WORLD NUCLEAR ASSOCIATION

World Uranium Mining Production

(Updated July 2017)

- **Over two-thirds of the world's production of uranium from mines is from Kazakhstan, Canada and Australia.**
- **An increasing amount of uranium, now 48%, is produced by in situ leaching.**
- **After a decade of falling mine production to 1993, output of uranium has generally risen since then and now meets almost all the demand for power generation.**

Kazakhstan produces the largest share of uranium from mines (39% of world supply from mines in 2016), followed by Canada (22%) and Australia (10%).

Production from mines (tonnes U)

Country	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Kazakhstan	6637	8521	14020	17803	19451	21317	22451	23127	23800	24575
Canada	9476	9000	10173	9783	9145	8999	9331	9134	13325	14039
Australia	8611	8430	7982	5900	5983	6991	6350	5001	5654	6315
Niger	3153	3032	3243	4198	4351	4667	4518	4057	4116	3479
Namibia	2879	4366	4626	4496	3258	4495	4323	3255	2993	3654
Russia	3413	3521	3564	3562	2993	2872	3135	2990	3055	3004
Uzbekistan (est)	2320	2338	2429	2400	2500	2400	2400	2400	2385	2404
China (est)	712	769	750	827	885	1500	1500	1500	1616	1616
USA	1654	1430	1453	1660	1537	1596	1792	1919	1256	1125
Ukraine (est)	846	800	840	850	890	960	922	926	1200	1005
South Africa	539	655	563	583	582	465	531	573	393	490
India (est)	270	271	290	400	400	385	385	385	385	385
Czech Republic	306	263	258	254	229	228	215	193	155	138
Romania (est)	77	77	75	77	77	90	77	77	77	50
Pakistan (est)	45	45	50	45	45	45	45	45	45	45
Brazil (est)	299	330	345	148	265	326	192	55	40	44
France	4	5	8	7	6	3	5	3	2	0
Germany	41	0	0	8	51	50	27	33	0	0
Malawi			104	670	846	1101	1132	369	0	0
Total world	**41 282**	**43 764**	**50 772**	**53 671**	**53 493**	**58 489**	**59,331**	**56,041**	**60,496**	**62,366**
tonnes U_3O_8	48 683	51 611	59 875	63 295	63 084	68 976	69,969	66,089	71,343	73,548
% of world demand*	64%	68%	78%	78%	85%	86%	92%	85%	90%	98%

*Data from the World Nuclear Association

Mining methods have been changing. In 1990, 55% of world production came from underground mines, but this shrunk dramatically to 1999, with 33% then. From 2000 the new Canadian mines increased it again, and with Olympic Dam it is now about 40%. In situ leach (ISL, or ISR) mining has been steadily increasing its share of the total, mainly due to Kazakhstan, and in 2014 for the first time was more than half of production. In 2016 production was as follows:

Method	tonnes U	%
In situ leach (ISL)	30,062	48%
Underground & open pit (except Olympic Dam)*	29,030	47%
By-product*	3,274	5%

* Considering Olympic Dam as by-product rather than in underground category

Conventional mines have a mill where the ore is crushed, ground and then leached with sulfuric acid to dissolve the uranium oxides. At the mill of a conventional mine, or the treatment plant of an ISL operation, the uranium then separated by ion exchange before being dried and packed, usually as U_3O_8. Some mills and ISL operations (especially in the USA) use carbonate leaching instead of sulfuric acid, depending on the orebody. Where uranium is recovered as a by-product, eg of copper or phosphate, the treatment process is likely to be more complex.

During the 1990s the uranium production industry was consolidated by takeovers, mergers and closures, but this has diversified again with Kazakhstan's multinational ownership structure. Over half of uranium mine production is from state-owned mining companies, some of which prioritise secure supply over market considerations. In 2015, eleven companies marketed 89% of the world's uranium mine production:

Company	tonnes U	%
KazAtomProm	12986	21
Cameco	10438	17
Areva	8176	13
ARMZ - Uranium One	7913	13
BHP Billiton	3233	5
CNNC & CGN	2964	4
Rio Tinto	2440	4
Navoi	2404	4
Paladin	1420	2
Other	10,455	17
Total	**62,366**	**100%**

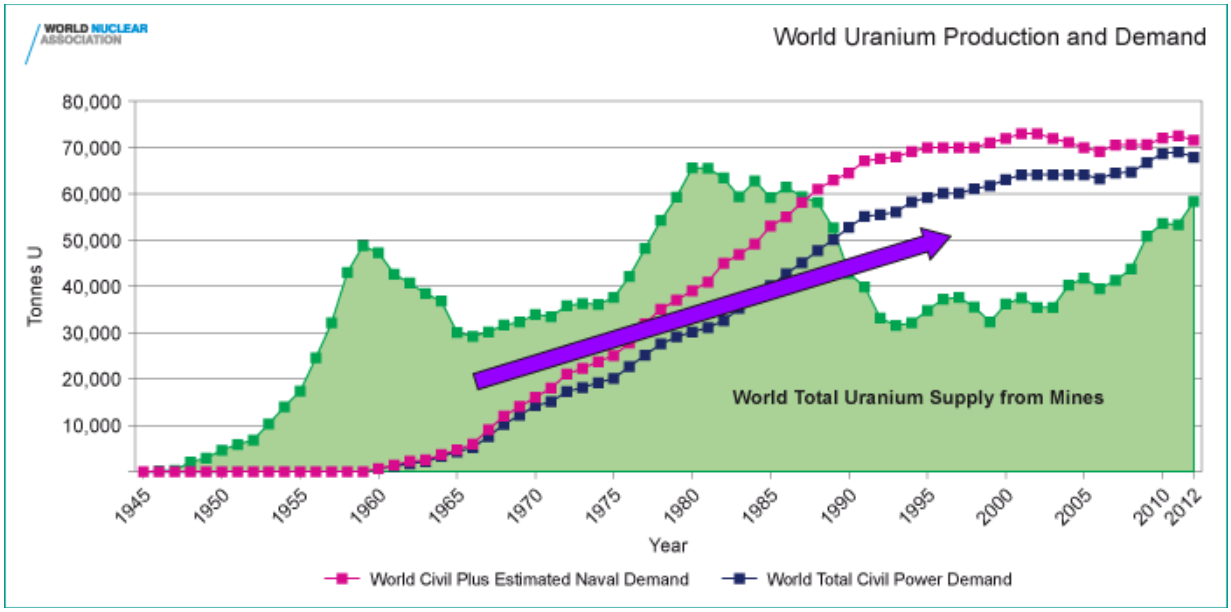
Note that these figures are based on marketed share of production, not joint venture shares.
Areva equity share was 8432 tU.

The largest-producing uranium mines in 2016 were:

Mine	Country	Main owner	Type	Production (tU)	% of world
McArthur River	Canada	Cameco (69.8%)	underground	6945	11
Cigar Lake	Canada	Cameco (50%)	underground	6666	11
Tortkuduk & Myunkum	Kazakhstan	Katco JV/Areva	ISL	4002	6

Mine	Country	Main owner	Type	Production (tU)	% of world
Olympic Dam	Australia	BHP Billiton	by-product/ underground	3233	5
Inkai	Kazakhstan	Inkai JV/Cameco	ISL	2291	4
SOMAIR	Niger	Areva (63.6%)	open pit	2164	4
Budenovskoye 2	Kazakhstan	Karatau JV/Kazatomprom-Uranium One	ISL	2081	3
South Inkai	Kazakhstan	Betpak Dala JV/Uranium One	ISL	2056	3
Central Mynkuduk	Kazakhstan	Ken Dala JSC/ Kazatomprom	ISL	2010	3
Ranger	Australia	Rio Tinto (68%)	open pit	1994	3
Langer Heinrich	Namibia	Paladin	open pit	1893	3
Priargunsky	Russia	ARMZ	underground	1873	3
Kharasan 2	Kazakhstan	Baiken-U	ISL	1838	3
Budenovskoye 1, 3 & 4	Kazakhstan	Akbastau JV/Kazatomprom-Uranium One	ISL	1743	3
Rossing	Namibia	Rio Tinto (68.6%)	open pit	1569	2.5
Top 15 total				**42,367**	**68%**

In some rows there is more than a single mine, but they are operated and reported jointly.



Source: World Nuclear Association

New mines

Following the recovery of uranium prices since about 2003, there was a lot of activity in preparing to open new mines in many countries. The World Nuclear Association reference scenario projects world uranium demand as about 67,867 tU in 2017, and most of this will need to come directly from mines. Due to the absence of Japanese consumption in the last couple of years and low prices there has been some stockpile build-up over 2013-16, which will come in as secondary supply in the next few years. The large Husab mine in Namibia is in 2017 ramping up towards full production of 5500 tU/yr.

Some of the new mines expected to start production in the next few years are:

Salamanca	Spain	2017
Mulga Rock	Australia	
Wiluna	Australia	
Canyon	USA	
Arrow	Canada	

Known recoverable resources of uranium 2015

	tonnes U	percentage of world
Australia	1,664,100	29%
Kazakhstan	745,300	13%
Canada	509,800	9%
Russian Fed	507,800	9%
South Africa	322,400	6%
Niger	291,500	5%
Brazil	276,800	5%
China	272,500	5%
Namibia	267,000	5%
Mongolia	141,500	2%
Uzbekistan	131,100	2%
Ukraine	115,800	2%
Botswana	73,500	1%
USA	62,900	1%
Tanzania	58,100	1%
Jordan	47,700	1%
Other	232,400	4%
World total	**5,718,400**	

Reasonably assured resources plus inferred resources (recoverable), to US$ 130/kg U, 1/1/15, from OECD NEA & IAEA, *Uranium 2016: Resources, Production and Demand* ('Red Book').
The total to US$ 260/kg U is 7.64 million tonnes U.

Sources:
World Nuclear Association

WORLD NUCLEAR ASSOCIATION

US Uranium Mining and Exploration

(Updated August 2017)

Uranium mining in the USA today is undertaken by few companies on a relatively small scale. Uranium exploration is undertaken by many companies, often going over areas that were mined in the 1950s-80s.

Uranium production is from one mill (White Mesa, Utah) fed by four or five underground mines and several in-situ leach (ISL) operations[1] is tabulated below.

Year	Tonnes U produced	Hardrock mills	ISL operations at year end
2006	1583	White Mesa	Crow Butte, Smith Ranch-Highland, Alta Mesa, Kingsville Dome, Vasquez
2007	1748	White Mesa	Crow Butte, Smith Ranch-Highland, Alta Mesa, Kingsville Dome
2008	1503	White Mesa	Crow Butte, Smith Ranch-Highland, Alta Mesa, Rosita, Kingsville Dome
2009	1445	White Mesa	Crow Butte, Smith Ranch-Highland, Alta Mesa
2010	1630	White Mesa	Crow Butte, Smith Ranch-Highland, Alta Mesa, La Palangana
2011	1538	White Mesa	Crow Butte, Smith Ranch-Highland, Alta Mesa, La Palangana, Willow Creek
2012	1596	White Mesa	Crow Butte, Smith Ranch-Highland, Alta Mesa, La Palangana, Willow Creek
2013	1796	White Mesa	Crow Butte, Smith Ranch-Highland, Alta Mesa, Hobson/La Palangana, Willow Creek, Lost Creek
2014	1919	White Mesa	Crow Butte, Smith Ranch-Highland, Hobson/La Palangana, Willow Creek, Lost Creek, Nichols Ranch
2015	1271	White Mesa	Crow Butte, Smith Ranch-Highland, Hobson/La Palangana, Willow Creek, Lost Creek, Nichols Ranch
2016	1126	White Mesa	Crow Butte, Smith Ranch-Highland, Willow Creek, Lost Creek, Nichols Ranch, Lance

Most US uranium-producing states are 'agreement states' *vis a vis* the Nuclear Regulatory Commission (NRC) and have authority to issue permits and regulate uranium mining and milling. NRC's role is then minimal. In February 2015 Wyoming, the major uranium production state, passed legislation to make it an agreement state, along with all the other uranium-producing states. It expects to achieve this status in 2018. Five of the six operating uranium recovery facilities under NRC oversight in 2016 are in Wyoming. Under a 2010 agreement the NRC collaborates with the federal Bureau of Land Management (BLM) on environmental assessment of mine proposals. A majority of US uranium production comes from Wyoming's Powder River Basin.

However, land access is partly controlled by the US government, and in 2011 the Interior Secretary issued an order banning new hardrock uranium mining in about 4000 square km of land in Arizona for 20 years, which sterilized 145,000 tU of known resources according to the NEI and also much prospective ground. The industry contends that uranium exploration and mining here would not compromise the Grand Canyon watershed. The land is not within the Grand Canyon National Park or the buffer zone protecting the national park. The industry contends that

that the land withdrawal is not justified by information in the Interior Department's environmental assessment, and is an "arbitrary agency action" under the Administrative Procedure Act, and that it fails to comply with the National Environmental Policy Act by failing to take the "hard look" at the withdrawal's consequences that the US Supreme Court required in a unanimous 1989 decision. In March 2013 a US District Court judge declined to overturn the mining ban, and in October 2014 the US District Court affirmed the ban. NEI comment.

In January 2015 the Environment Protection Agency (EPA) proposed new health and environmental protection standards for uranium extraction including tighter groundwater quality and monitoring standards, under the Uranium Mill Tailings Radiation Control Act of 1978. The proposed standards address the increased use of ISL for uranium recovery in the USA. The proposed rule describes how ISL facilities are to characterize groundwater chemistry before commencing uranium mining. The rule would also require compliance with whichever standard is most stringent from the Safe Drinking Water Act, the Resource Conservation and Recovery Act, or the Uranium Mill Tailings Radiation Control Act for each of 13 groundwater constituents: arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver, nitrate, molybdenum, radium, total uranium, and gross alpha particle activity. The final post-mining water quality would need to match the original, and be monitored for 30 years by the operator unless chemistry was satisfactory and stable over three years. The final standards will be administered by the NRC.

US Uranium Production, tonnes U

Company	ISL operations, hard rock mill	2013	2014	2015	2016	2017
Cameco	Smith Ranch - Highland, WY	646	815	556	358	
Cameco	Crow Butte, NE	272	227	152	89	
Uranium One	Willow Creek, WY	362	217	45	23	
Ur-Energy	Losy Creek, WY	51	211	280 drummed (301 captured)	216 drummed (207 captured)	
Penisnula/Strata	Lance, WY	0	0	0	49	plan 60
UEC	Hobson - La Palangana, TX		10	4	0?	
EFRC (Uranerz)	Nichols Ranch, WY	0	77	105 (66 after acquisition)	129	plan 135
EFRC (Mestena U)	Alta Mesa, TX	?	0	0	0	
EFRC	White Mesa mill	388	362	114	262	plan 145
Total		**1796**	**1919**	**1256**	**1126**	

Mining and exploration projects

Conventional (non-ISL) uranium mining is resuming in the USA after some years (though Cotter Corporation produced 38 tonnes U through its 400 t/day Cañon City mill, Colorado in 2005).

In 2016 the EIA estimated that US uranium resources were 25,400 tU recoverable at $78/kgU, 64,000 tU at $130/kgU and 139,500 tU at $260/kg. Estimated reserves for mines in production were 6167 tU at <$130/kg. The resource data is consistent with slightly older data in the 2016 edition of the 'Red Book'.

Energy Fuels – EFRC

Energy Fuels Resources Corporation (EFRC, a Colorado-based subsidiary of Energy Fuels Inc of Toronto) is the largest US uranium mining company (after Cameco). In April 2012 EFRC agreed to take over all Denison Mines' US assets and operations, including the White Mesa mill, in a C$106 million merger. In August 2013 Energy Fuels took over Strathmore Minerals in a C$29 million deal. Korea Electric Power Co. (KEPCO) is the largest shareholder in

both companies, with 9.1% and 11.7% respectively. It supported the takeover and holds 9.6% of the expanded company. In June 2015 Energy Fuels Inc completed its $150 million takeover of Uranerz Energy Corp. Its takeover of Mestena Uranium was finalised in mid-2016.

White Mesa Mill (Energy Fuels)

EFRC claims a licensed capacity of over 4400 tU per year, and says it has the capability – with improved uranium prices and the receipt of additional permits – to produce about half of that on a sustained basis. However, it expected to produce 366 tU in 2016, including 135 tU from Nichols Ranch and 230 tU through the White Mesa mill, including 164 tU from Pinenut project, and 308 tU in 2017, including 173 tU from White Mesa. Actual production in 2016 was 129 tU, and 2017 plan is for 135 tU.

Uranerz Energy Corp, which became part of Energy Fuels in mid-2015, received an NRC materials licence for its Nichols Ranch ISL operation in the Powder River Basin of Wyoming in July 2011, and its final state approval in October 2012. Production commenced in April 2014, with loaded resin being trucked to Cameco's Smith Ranch plant for recovery, under a toll processing agreement. The initial plant capacity is 300 tU/yr. EFRC built its own elution plant, which was commissioned and licensed early in 2016.

EFRC has NI 43-101 compliant resources of 6060 tU at about 0.1% U in seven Uranerz deposits, including measured & indicated resources of 1137 tU for Nichols Ranch itself, 860 tU for Hank, 1100 tU for West North-Butte and 1655 tU measured and indicated resources at about half the grades of these – 0.048% U – at Reno Creek, 30 km east of Nichols Ranch. The company added the contiguous Jane Dough permit area, with 1052 tU, to the Nichols Ranch project, and this was fully permitted by the NRC in March 2017. It will be followed by Hank as a satellite operation, and the BLM issued approval for this in mid-2015.

EFRC's main pending development projects in 2015 were Sheep Mountain WY, Roca Honda NM, and Bullfrog in the Henry Mountains complex of Utah. Other EFRC mines would "remain on standby until [market] conditions improve." However, in 2016 Canyon mine in Arizona was being promoted as an early prospective start-up – see below.

The White Mesa mill in southeastern Utah (near 'Four Corners'), had been operated by Denison Mines for its own and purchased ore (the company advertised its ore-buying program), as well as doing some toll milling. The mill was built in 1980 and refurbished in 2007, with versatile licensed capacity of about 3000 tU/yr. It has had two types of feed: from Colorado Plateau: carnotite in sandstone; and from Arizona Strip breccia pipes: fine grain uraninite. It has an alternate feed circuit to process "other uranium-bearing materials, such as remediation wastes and those derived from uranium conversion and other metal processing" which may be very high-grade Treatment of these may be separate, or blended in the primary leach circuit, and it has recovered over 550 tU from such sources since 2005. It also has a vanadium co-product recovery circuit, unused at present. In addition it calcines UO_4 from Nichols Ranch. Some ore is hauled over 1000 km to the mill.

White Mesa produced 21% of US uranium over 2011-15. It produced 476 tU over 15 months to the end of 2013, with 700 t of vanadium oxide.* Some of its feed in 2013 came from Cameco's Blind River tailings in Ontario. Production in 2014 was 362 tU, and 114 tU in 2015, of which 28 tonnes was toll processed for a third party. The company closed the mill in late 2015 on account of market conditions, while stockpiling feed to meet sales commitments in 2016. Production of 262 tU in 2016 was expected to come from stockpiled Pinenut ore (177 tU), stockpiled alternate feed materials (64 tU) and recovery from tailings pond returns (10 tU). Production in 2017 is expected to be about 145 tU for EFRC, up to one-third from alternate feed materials and the balance from tailings pond returns. In addition, a "substantial" toll processing contract for alternate feed materials could yield 400 tU for its undisclosed owner.

* During 2013 the White Mesa mill processed 18,370 t of Arizona 1 ore, 2,052 t of Pinenut ore, 11,181 t of Daneros ore, 41,782 t of Pandora ore, 40,669 tons of Beaver ore, and 8,894 t of purchased ore to produce 388 tU.

EFRC has several mines in the Uravan Mineral Belt on the Colorado Plateau (straddling the Utah-Colorado border) containing 2100 tU in placer deposits plus vanadium co-product (Uravan = uranium + vanadium). These La Sal Complex mines about 100 km northeast of the White Mesa mill comprise La Sal, Beaver and Pandora which are mature operating mines with extensive interconnected underground workings. In October 2012 EFRC said it would place Beaver and La Sal on standby, pending uranium market improvement and would finish mining at Pandora by mid-year due to depleted resources. EFRC's nearby Energy Queen mine in Utah was refurbished for 2008 reopening, and is licensed but not operating.

EFRC's Henry Mountains deposits in Utah including Tony M, Southwest and Bullfrog have 4900 tU as indicated resources at over 0.2% and inferred resources of 3100 tU, both NI 43-101 compliant. All these are some 120 km west of the White Mesa mill. Denison began production from the Tony M mine in 2007, but late in 2008 put it on care and maintenance. The company was intending to spend $35 million on the adjacent new Bullfrog mine, but it was put on hold in 2008.

EFRC's Daneros deposit in southeastern Utah was was the main asset of White Canyon Uranium which Denison bought for $57 million in 2011. It has been mined since December 2009 and ore was trucked 100 km to the White Mesa mill for treatment and recovery of U_3O_8 product. Ore produced during the development phase was sold to Denison, and from there a three-year toll treatment agreement came into effect. JORC-compliant resource figures of 447 tU in 0.22%U ore were quoted in August 2010, and production is planned to be 227 tU/yr. In October 2012 EFRC put Daneros on standby, pending uranium market improvement.

Denison also had four old mines in the Arizona Strip of north central Arizona, along with some new deposits there, though all these are some 500 km southwest from the White Mesa mill and some may be impacted by the Bureau of Land Management decision to stall developments near the Grand Canyon. The Arizona One underground mine resumed production in 2009, but known resources were depleted early in 2014, so it closed. Denison had applied for licences for its nearby Pinenut and EZ mines. Pinenut was mined in the 1980s and produced 200 tU then, with a shaft 410 m deep. EFRC brought the mine into production in 2013 but closed it in mid-2015 pending uranium price improvement. Ore from both mines was milled at White Mesa, as will be for that from Canyon.

In Arizona, the Canyon mine, which was originally licensed in 1986 and fully permitted, has 936 tU as measured and indicated resources at 0.75%U (NI 43-101 compliant), with 5400 t copper, increased by drilling undertaken into 2017. The development was on hold pending resolution of a dispute with the US Forest Service, but the company is

preparing to reopen it with personnel from Pinenut. The surface facilities are complete along with shaft sinking to 443 metres. Ore will be trucked to the White Mesa mill. The mine is now prospectively EFRC's prime producer. Copper is a likely significant by-product, and metallurgical tests to optimize its recovery will continue into 2018. Canyon will be the ninth breccia pipe deposit mined for uranium.

In 2015 EFRC subsidiary EFR Arizona Strip acquired the Wate deposit from Vane Minerals and Anfield Resources. It is a high-grade breccia pipe deposit like Pinenut, Canyon and Arizona One mines. The company expects a mining licence by mid-2017 and anticipates processing production from Wate at its White Mesa mill. The deposit has 432 tU at an average grade of 0.67%U (NI 43-101 compliant) inferred resources. Also in Arizona, the EZ mine is subject to land use restrictions by the Bureau of Land Management (BLM). It has 810 tU as inferred resources.

EFRC's Sheep Mountain, Wyoming deposit has 11,700 tU measured and indicated resources at 0.1%U, including 7100 probable reserves. In 2009, Titan Uranium Inc bought Uranium One's 50% interest in it, and it then transferred to EFRC in a 2012 merger with Titan. Underground development took place in the 1970s. Titan undertook a prefeasibility study on mining the Congo open pit and underground, with heap leaching recovery, to produce 580 tU/yr. EFRC has updated this preliminary feasibility study for the whole project, and proposed development was in conjunction with Gas Hills, only 45 km north. The BLM was preparing an EIS for the project, with approval expected in mid-2016. The state mine permit for major expansion was issued in July 2015.

Strathmore had been working towards bringing its Gas Hills properties in central Wyoming into production, possibly in conjunction with Juniper Ridge, or with EFRC's Sheep Mountain nearby, or both. In mid-2017 these two deposits were acquired by URZ Energy Corp.

In New Mexico, Strathmore submitted a mining permit application in October 2009 for Roca Honda (then 60% -owned, with Sumitomo 40%) in the Grants mineral district. Original plans assumed that a new mill would be built, but the White Mesa mill about 180 km away in southeastern Utah is likely to be used. In June 2015 EFRC bought URI's partly-developed Roca Honda mineral properties adjacent to EFRC's (ex Strathmore) Roca Honda and then in 2016 bought out Sumitomo's 40% share for $6.3 million, giving it full ownership. The company hopes to complete permitting in 2017 and has signed an agreement to buy Sumitomo's 40% share, giving it full ownership. Total measured and indicated resources are 6500 tU grading 0.41%U and inferred resources of 4300 tU grading 0.40%U (Feb 2016). Production potential is about 1100 tU/yr over nine years. The company hopes to complete permitting in 2017.

The merged company also has other projects in the Grants mineral district of New Mexico, including: Marquez with 3500 tU as indicated resource, Dalton Pass with ISL potential and 1000 tU measured & indicated resource, and Nose Rock, deep in hard rock with 1160 tU measured & indicated resource. All these are NI 43-101 compliant. In November 2015 EFRC sold Marquez, Nose Rock and other small deposits in Arizona and Utah to Vancouver-based enCore Energy Corp.

Other EFRC Uravan mines operating in 2007-08 but now closed include Topaz, West Sunday and Sunday/St. Jude in the Sunday complex in Colorado. There are no plans to bring the other mine there, Van 4, into production. EFRC reopened the refurbished Whirlwind mine (including Packrat and Bonanza) following Bureau of Land Management and state approval, but put it on standby in 2009. It had 425 tU measured and indicated resources and 770 tU inferred resources. It appears that these properties have been sold to Western Uranium Corp.

EFRC in March 2011 had received a Colorado state licence to build the new 330 tU/yr Pinon Ridge mill for ore from its northern Arizona mines, plus possible toll treatment, but this was overturned on appeal in June 2012, pending a further public hearing. The state's radioactive materials licence was reissued in April 2013, but plans were then put on hold and the project was sold to Western Uranium Corp. The company had been seeking $140 million finance for the mill, which would also produce 1700 t/yr of vanadium oxide.

In June 2016 EFRC took over Mestena Uranium LLC, a private Texas company. Its Alta Mesa ISL plant in southern Texas was operating to the end of 2013 but is now on standby. It has about 385 tU/yr capacity and is understood to be a low-cost producer which could be brought on line as a third production centre for EFRC within six months. EFRC announced NI 43-101 compliant measured and indicated resources of 1390 tU and inferred resources of 6460 tU.

Western Uranium

In July 2014 Western Uranium Corp (formerly Homeland Uranium) agreed to buy from EFRC some of its non-core assets including eight mining properties along the Colorado-Utah border and the licence for the Pinon Ridge mill (see above) for $33 million. The former comprise the fully-permitted Sunday complex, the Sage and Van 4 mines, the Wilhunt, San Rafael, Farmer Girl, Dun and the Yellow Cat projects. EFRC will get a royalty of $3 per tonne on Pinion Ridge mill throughput, and one percent of sales. The licence is now held by Pinon Ridge Resources Corporation. In mid-2015 the company announced NI 43-101 compliant measured and indicated resources of 390 tU at 0.21%U and 735 tU inferred resources at 0.31%U for the Sunday mine complex covering the southern third of the Uravan mineral belt in Colorado.

In 2015 Western Uranium Corp took over Black Range Minerals Ltd in a $14.5 million transaction, making it a subsidiary and acquiring the 11,500 tU Hansen and Taylor Ranch deposits in Colorado with 15,200 tU measured and indicated resources grading 0.053%U. Including inferred resources, the whole project has 35,000 tU grading 0.05%U. Hansen was licensed for mining in 1981, but stalled due to low uranium prices.

Black Range has a joint venture with Ablation Technologies LLC to commercialize its ablation mineral concentration process (AMT). This agreement allows Western Uranium to utilize this technology at the Hansen-Taylor Ranch Project and at other projects. The merger terms with Western require Black Range to move an ablation pilot plant to its Sunday mine underground complex in southwest Colorado, bought from EFRC in 2014. A 5 t/hr ablation unit is operating there, and a 20 t/hr commercial-scale one will join it by mid-2016. The company said: "Production tests indicate that the patented mining process could substantially reduce the cost of producing uranium concentrates from both the company's mines, and potentially from other sandstone hosted deposits globally."

In late 2016 Western Mining signed an agreement with Pinon Ridge Corporation to use ablation technology at its subsidiary's mill. The technology is being evaluated by the Colorado Department of Public Health and the Environment (CDPHE) with advice from the NRC.

Uranium One

Toronto-based Uranium One's main interests are in ISL projects. Uranium One is now wholly-owned by Russia's ARMZ, and Uranium One Holdings is responsible for all Rosatom's uranium mining outside Russia. US operations have current design capacity of 500 tU/yr and maximum potential of 1400 tU/yr. All are ISL.

In Wyoming, Uranium One USA had production from its Willow Creek ISL project in the Powder River Basin from 2011. This comprises several small mines and the Irigaray mill, mostly acquired from Areva in 2009 for $35 million. In December 2010, the NRC licensed the Irigaray mill to produce up to 960 tU/yr (it operated at 500 tU/yr in 2011), and for nearby Christiansen Ranch to restart operations (it had been shut down since 2000 and restarted in January 2011). Production from its three small mines (Moore Ranch, Peterson Ranch, Nine Mile) and from Christiansen Ranch itself is from loaded resin trucked to Irigaray from satellite plants. Overall Willow Creek produced 362 tU in 2013 at a cost of $36/lb and 217 tU in 2014. Wellfield development was put on hold in 2014 until prices improve, and production wound down in 2015, with only 14 tU produced in Q2. Willow Creek total resources (NI 43-101) are 6500 tU. The Irigaray plant also toll processes loaded resin from Peninsula's Lance project on the east side of Powder River basin, pending construction of a plant there, and in December 2016 it signed an agreement to toll process Anfield's loaded resin also, to produce about 193 tU.

The Nuclear Regulatory Commission issued a licence to Uranium One Americas for Moore Ranch in October 2010, to start production in 2012, but development is suspended. Uranium One's additional projects in the Powder River Basin, including Ludeman, Allemand-Ross, Barge (1770 tU), Pine Tree and Ross Flats could also be developed as satellite operations with final processing through the Irigaray central plant. Uranium One has some 4000 tU as measured resources (2235 t at Moore Ranch) and 23,000 tU as indicated resources in the state. Ludeman is quoted with 4200 tU total resources (NI 43-101). It also had plans for production from Antelope and JAB in the Great Divide Basin, but these were deferred due to endangered species concerns.

Uranium One deposits in the Great Divide Basin of Wyoming are Antelope, JAB, Twin Buttes, Crooks Creek, Bull Springs, Stewart Creek, Cyclone Rim and West JAB.

In 2016 Uranium One sold 24 Wyoming properties in the Black Hills, Powder River Basin, Great Divide Basin, Laramie Basin, Shirley Basin and Wind River Basin areas to Anfield Resources for $6.55 million.

In 2010, Uranium One sold a number of Utah and Colorado claims and two Utah leases, including the Sage mine, to Colorado Plateau Partners (CPP), a joint venture between Energy Fuels Inc of Toronto (see EFRC above) and Royal Resources Ltd of Australia.

Cameco

Cameco's US subsidiary Cameco Resources Inc operates the Smith Ranch-Highland mine in Wyoming's Powder River basin and the Crow Butte mine in Nebraska, both of them ISL operations, and producing nearly 1200 tonnes U between them in 2009. The company is aiming to increase production from these mines and adjacent properties including Reynolds Ranch to 1,770 tU/y when markets improve. However, in 2016 production was curtailed due to market conditions.

Smith Ranch-Highland produced 815 tU in 2014 and 556 tU in 2015, including North Butte. North Butte-Brown Ranch is a satellite plant about 40 km north which started production in May 2013 and will ramp up to 270 tU/yr. Licensed wellfield capacity of the whole operation is 1156 tU. Reserves total 3080 tU, plus 11,000 tU measured and indicated resources (Dec 2015).

Cameco also has a Gas Hills-Peach project 90 km west of Casper in Wyoming which is permitted but on hold, with 5100 tU measured and indicated resources.

In 2015 Crow Butte produced 152 tU, though licensed capacity is 770 tU. It has 5800 tU resources grading 0.22%U.

UEC

Uranium Energy Corporation (UEC) in October 2009 bought the small but recently-refurbished Hobson mill in southern Texas from Uranium One (it had been shut since 1991). UEC then made Hobson the basis and hub of its Texas uranium projects. Hobson had 385 t/yr capacity, but UEC says it is now 1150 tU/yr, in 2011-12 it processed 90 tU. It recovers uranium from loaded resin trucked there from the Palangana ISL mine, to which will be added loaded resin from satellite plants at Goliad and Burke Hollow, followed by Nichols and Salvo.

Production commenced at Palangana in November 2010 – the first US ISL operation to start in five years. By the end of 2011 UEC had obtained all the necessary permits to develop its Goliad ISL project, 70 km east of the Hobson mill, for production anticipated from mid2014. Palangana has 410 tU measured and indicated resources grading 0.114%U in two orebodies and 445 tU inferred resources at 0.15%U in six others, while Goliad has 2100 tU measured & indicated resources at 0.04%U, all NI 43-101 compliant. Future ISL satellites are Burke Hollow, 86 km SE of Hobson and with 1100 tU inferred resource estimate, Salvo, with 1100 tU inferred resource grading 0.07%U, then Nichols with 500 tU inferred located close to Hobson mill, and Burke Hollow (1100 tU inferred) and Channen. Salvo and Channen are 70-85 km from Hobson. Longhorn is recently acquired, and will feed Hobson mill. UEC claims cash cost of $20 per pound over 2010-12 for its ISL production, excluding royalties. However, in September 2013 UEC said it would slow production at Palangana pending recovery in uranium prices, while it focuses on Goliard and Burke Hollow. UEC lodged final permit applications for Burke Hollow late in 2014, and some permits were issued in May and July 2015, and December 2016. Further approvals from EPA are awaited.

UEC's Anderson project northwest of Phoenix in central west Arizona was formerly mined in 1950s to yield 12,800 tU. It has 6000 tU indicated and 960 tU inferred resources at 0.024%U accessible by open pit mining, with two-thirds as much again (mostly inferred) accessible underground (NI 43-101). UEC expects to produce 6200 tU over 14 years using heap leach and transport of loaded resin to White Mesa mill in Utah.

In 2007 UEC bought the New River, now Los Cuatros Uranium Project in central Arizona with a historic resource estimate of 5000 tU in shallow low-grade ore. Its Workman Creek deposit there has 2100 tU inferred resource at 0.073%U.

UEC has a NI 43-101 inferred resource for its Slick Rock project in western Colorado, of 4470 tU grading 0.19%U. Vanadium is also present. Several other prospects are nearby.

UEC acquired 97% of the fully-permitted Reno Creek in Wyoming's Powder River Basin from Pacific Road Resources Funds and the balance from the AUC subsidiary of Bayswater Uranium Corporation of Canada, which had a positive pre-feasibility study on mining its Reno Creek and Southwest Reno Creek deposits in Wyoming, held by its affiliate AUC. They have a NI 43-101 measured and indicated resource of 8470 tU @ 0.035%U suitable for ISL, plus a small inferred resource. The project would have up to 18 wellfields and a central processing plant producing 330 tU/yr initially then up to 770 tU/yr as the market permits, and would take 18 months to bring online. It is 30 km southeast of Uranium One's Willow Creek and 50 km north of Cameco's Smith Ranch. In July 2015 the Wyoming Department of Environmental Quality (WDEQ) Land Quality Division issued AUC a permit to mine for the Reno Creek uranium project, producing up to 770 tU per year. In February 2017 the NRC issued an operating licence for the project at this production level, though AUC said it did not intend to proceed immediately.

URI / Westwater Resources

Uranium Resources Inc (URI) began operations in 1977 in south Texas. It developed and produced over 216 tU from the Longoria and Benavides projects in the early 1980s, then 2350 tU from Kingsville Dome and Rosita through to 1999.

In south Texas, URI commenced production from its Vasquez ISL mine in 2004 at about 50 tU/yr and from Kingsville Dome in 2006. Vasquez peaked in 2006 and is now depleted (30 tU in 2007, 9 tU in 2008). Rosita restarted production in 2008 with oxygen injection but was then closed as uneconomic after 3 tU was recovered. Kingsville Dome produced 67 tU in 2008 and 19 tU in 2009. It was closed in June 2009 due to low uranium prices, and the wellfield has been remediated using reverse osmosis along with Vasquez and Rosita wellfields. The 300 tU/yr Kingsville Dome plant is being maintained on standby, with potential for accepting resin from four satellite IX plants. URI earlier said that it did not intend to revive its Texas operations, with total reserves at Kingsville and Rosita wellfields of only 260 tU. However, in December 2013 it said that it remained "committed to developing uranium in South Texas as we aim to leverage our two processing plants in the region" – Kingsville Dome and Rosita. Butler Ranch, also ISL and acquired in 2014, is 160 km north of the Kingsville Dome plant, and Rosita is 65 km northwest of the plant. In 2015 URI was actively evaluating Butler Ranch and Alta Mesa Este.

URI owned several Grants mineral belt properties in western New Mexico which hold 39,000 tU, and from which it hoped to produce 2000-3000 tU/yr from ISL. URI subsidiary Hydro Resources Inc was licensed in 1994 to mine the Crownpoint and Church Rock ISL deposits in New Mexico, and after years of opposition the licence was validated by the Nuclear Regulatory Commission in 2006 and then reactivated in 2011. URI planned to produce 385 tU/yr from Church Rock/Mancos from 2013, as the first of URI's New Mexico properties to develop, subject to further permitting.

Nose Rock, Roca Honda and West Largo/Ambrosia Lake are other URI properties in the Grants mineral belt. URI has a licence to build a processing plant in the area.

In June 2015 URI sold its partly-developed Roca Honda mineral properties adjacent to EFRC's Roca Honda project to EFRC, while retaining some royalty rights. In partial exchange it received from EFRC some claims adjacent to its Church Rock prospect. These have a historic resource estimate of 4200 tU based on a previous owner's 1979 data. URI has a licence to build a processing plant in the area. Following the takeover of Anatolia Energy, in November 2015 URI agreed to sell its Crownpoint and Church Rock properties to Laramide Resources for $12.5 million, and this was confirmed in April 2016 by way of selling Hydro Resources Inc and finalized at the end of the year.

URI In 2007 URI sought to buy Rio Algom Mining, with uranium properties and a licensed mill site at Ambrosia Lake in New Mexico, where it planned to construct a new mill to serve the Grants mineral belt. However, the deal was aborted in mid-2008.

URI also holds the Copper Mountain leases in Wyoming, with low-grade uranium mineralization (hardrock, not ISL) which was mined to 1971.

In June 2015 URI announced a takeover of Anatolia Energy, developing the Temrezli ISL uranium mine in Turkey. This was effectively a merger, and URI shareholders own about 59% of the merged company. As well as providing experienced staff, URI plans to move the Rosita processing plant to Turkey and finish doubling its capacity to 600 tU/yr – work that was halted in 2008.

In August 2017 URI changed its name to Westwater Resources (WWR) "to better reflect" its business plan to initiate lithium production.

Ur-Energy

Ur-Energy Inc (URE/ URG) has total about 8500 tU as NI 43-101 indicated resources in Wyoming, and claims potential for double that. Lost Creek in the Great Divide basin has 5100 tU measured and indicated resources at 0.04 %U and 2480 tU inferred (Nov 2015), including leases taken over from Uranium One in 2012. The company plans to produce 400 tU/yr from the Lost Creek wellfields and about the same from satellite operations through to 2031. The site is close to Rio Tinto's Sweetwater mill.

Production from Lost Creek commenced in mid-2013 after construction of a 770 tU/yr mill, following NRC licensing and Bureau of Land Management approval. Production in 2013 was 50.57 tU, in 2014 it was 211 tU, and 123 tU was produced by mid-2015.

In July 2014 the company announced measured and indicated resources of 3400 tU grading 0.194%U for its Shirley Basin project in Wyoming, 150 km east of Lost Creek. It was to be a satellite ISL operation from late 2017, with recovery at Lost Creek, for operating cost of $14.54 and total cost of $31.26 per pound U_3O_8. The ground was previously held by Pathfinder Mines Corp which Ur-Energy acquired in 2013, and it was mined conventionally to 1992, producing 10,800 tU. Average depth to orebody is 95 metres. (URZ's Shirley Basin property is separate.)

Peninsula/Strata

Australian-based Peninsula Energy commenced production from its Lance ISL project on the east side of Wyoming's Powder River Basin early in 2016. It has JORC-compliant resources (January 2013) of 19,800 tU at 0.041%U at Lance ISL, including 6130 tU as measured and indicated resources, held by the company's subsidiary Strata Energy Inc. The company plans a three-stage ramp-up eventually to 890 tU/yr from three production units – Ross, Kendrick and Barber – which will delay much capital expenditure and defer most sales until after 2018. These production units will feed into a central processing plant with an expandable capacity of up to 1154 tU per year (four modules of 288 tU/yr), commencing from Ross. The plant incorporates a restoration circuit with resin ion exchange (IX) then reverse osmosis (RO) to restore water quality of barren liquor to pre-mining levels.

A state permit to mine was issued in November 2012. From the NRC, the company received a source materials licence (SML), and a final supplemental environmental impact statement (SEIS) for both the plant and Ross wellfield in March-April 2014. The NRC authorised operation of the Ross wellfield in November 2015. Stage 1 of production involves trucking loaded resin 90 km west to Uranium One's Irigaray plant for elution. Stage 2 will increase the ion exchange capacity and bring the elution, precipitation, drying, and packaging processes in-house with the new central plant. The Kendrick, Richards and Barber production units to the south of Ross will be brought on line with amendments to Ross licences, the Barber wellfield and satellite plant being part of stage 3 ramp-up. A deep disposal well has been drilled to 2600 metres to a sandstone aquifer with low water quality. Vanadium may be a by-product – 2237 t V_2O_5 resources are identified for Ross and Kendrick.

In March 2016 Peninsula announced a long-term sales contract over 2020-30 for 1540 tU with a major European utility, with a provision to increase this to half of the Lance project's production from 2026. It already has sales contracts for 3045 tU with US and European utilities. Its first product was delivered in May 2016, and 2016 production was 49 tU.

In July 2015 Peninsula agreed to buy the nearby Hauber project from Aldershot Resources. This will likely become a satellite operation for Lance. Homestake produced 1000 tU in 1950-60s from Hauber, and in 2011 Bayswater Uranium was farming into the project. Aldershot quotes only about 250 tU resources NI 43-101 compliant, but estimates 1400 tU.

Azarga Uranium

Azarga Uranium Corp (formerly Powertech Uranium Corp) is proposing to develop two ISL mines: Centennial in northern Colorado, and Dewey-Burdock in South Dakota – in each case very close to the Wyoming border. Centennial has 4,430 tU in 0.08% ore and Dewey-Burdock 3310 tU indicated resources averaging 0.21%U (1.29 m% grade thickness) and 1340 tU inferred resources averaging 0.04%, both NI 43-101 compliant. Some 360 tU further inferred resources grading 0.144%U are above the water table. The company has applied to develop Dewey-Burdock, and a preliminary economic assessment in 2014 suggested 3700 tU ISL production over 11 years, with $27 million capital investment. The company has a full NRC operating licence, having overcome some local opposition. The project may still require EPA and state approval. Azarga also has 400 tU as indicated resources at its Aladdin project in Wyoming.

Anfield Resources

Vancouver-based Anfield Resources has 1780 tU at 0.25%U as measured and indicated resources at Velvet-Wood in Utah, the Frank M project in Utah, and a 50% interest in the Wate deposit in Arizona (432 tU), with EFRC. In June 2016 it reported a preliminary economic assessment of the Velvet-Wood project using heap leach or vat leach methods with an average output of 243 tU per year, for a total production of 1770 tU over a seven-year mine life. Under both scenarios, total capital expenditure is about $46 million, with direct operating costs of around $11 per pound. Other conventional mining properties are in Colorado.

Anfield's 'key asset' is the 1000 t/day Shootaring Canyon mill in Utah, which it bought, with some small stockpiles there, from Uranium One. Uranium One in 2007 had bought the mill* in southeast Utah with associated properties in four contiguous states for $50 million plus royalties, from US Energy. In October 2014 the Utah regulator agreed to transfer the licence to Anfield Resources and to give it a year to apply for licence renewal with necessary upgrading.

* US Energy had been planning to bring the mill back into production at a cost of $31 million. It was built in 1980 and then closed in 1982 and put on care and maintenance. (Uranium One had also secured the right to buy Rio Tinto's 3,000 t/day Sweetwater uranium mill and associated uranium properties in south-central Wyoming for $110 million, but in January 2007 Rio Tinto cancelled the deal.) In October 2013 Uranium One agreed to sell the Shootaring Canyon mill for $10 million to Black Range Minerals and also enter into a joint venture arrangement for all Uranium One's associated 'conventional' hard rock leases, where Black Range would progressively increase its equity, but this deal has lapsed due to regulatory problems. Black Range will concentrate on its Hansen project. In August 2014 Anfield Resources agreed to buy the mill and associated mining properties in three states, including Velvet-Wood in Utah, for $5 million.

In September 2016 Anfield completed the purchase of 24 Wyoming ISL properties in the Black Hills, Powder River Basin, Great Divide Basin, Laramie Basin, Shirley Basin and Wind River Basin areas from Uranium One for $6.55 million. NI 43-101 resource estimates for the properties are being prepared. The transaction also included an agreement-in-principle for Uranium One to process up to 193 tU per year of Anfield's loaded resin at Uranium One's Irigaray plant.

URZ Energy

Formerly Summit Point Uranium, URZ Energy is focused on Wyoming ISL prospects and owns the Gas Hills and Juniper Ridge deposits and a Shirley Basin project all in Wyoming and acquired in 2017 from EFRC (previously held by Strathmore). It also has exploration properties in the Uravan District, straddling the Colorado and Utah border.

Strathmore had been working towards bringing its Gas Hills properties in central Wyoming into production. Uranium is in roll-front sandstone deposits mostly amenable to open pit mining. A February 2012 agreement with KEPCO involved it in exploration, but this evidently terminated with Strathmore's purchase by EFRC in August 2013. Strathmore had intended to develop Juniper Ridge in conjunction with Gas Hills, or with EFRC's Sheep Mountain, or both. Juniper Ridge is 150 km south, straddling the Colorado border, and had been mined intermittently from 1954 to 1966. EFRC envisaged open pit mining and heap leach. In mid-2017 these two deposits were acquired by URZ Energy. Gas Hills then had 1820 tU at 0.083%U as indicated resources, and Juniper Ridge 2315 tU at 0.05%U indicated (NI 43-101 compliant).

Others, ISL

In New Mexico, Uranium International Corp (UIC) has announced 1,180 tU measured and indicated resource at Dalton Pass, with ISL potential. It also announced a 1,160 tU measured and indicated resource at Nose Rock, deep in hard rock. Both are NI 43-101 compliant, in the Grants mineral belt and owned by Strathmore Minerals. UIC has the option of earning a 65% share of each.

EnCore Energy Corp (Vancouver) bought Marquez and Nose Rock, adding to its Crownpoint and Hosta Butta deposits in New Mexico and also other small deposits in Arizona and Utah from EFRC in November 2014.

Laramide Resources Ltd bought URI's subsidiary Hydro Resources Inc to obtain the Church Rock and Crownpoint ISL properties in New Mexico for $12.5 million in April 2016, along with an option for URI to acquire Laramide's La Sal II in Utah for $4 million.

Others, hardrock

Cotter Corporation, a General Atomics subsidiary, was planning a $200 million rebuild of its Cañon City mill, where it expects to treat ore from the Mount Taylor mine in New Mexico. (Mount Taylor, which has been on standby since 1989, is owned by another General Atomics subsidiary, Rio Grande Resources Corporation.)

Neutron Energy Inc has taken full ownership of the Cebolleta Land Grant in New Mexico which has 8000 tU resources after mining took place 1975-81, producing 460 tU.

Yellowcake Mining Corp reports 5,000 tU reserves at its planned Beck mine in the Uravan area of Colorado and agreed in May 2008 to sell a 50% stake in it to Korea Electric Power Corp (KEPCO). However, in February 2009, KEPCO withdrew, leaving the project bereft of funds. The company had joint ventures with Strathmore Minerals for Juniper Ridge and a Gas Hills prospect in Wyoming, but these were terminated in 2008. In 2010 Strathmore agreed to sell Juniper Ridge to Crosshair Energy, but this agreement terminated in 2012.

Crosshair Energy has the Bootheel project in Wyoming with about 1780 tU resources.

Bluerock Energy Corporation has shipped the first ore from development of the J-Bird mine in Colorado to Denison's White Mesa mill in Utah.

Laramide Resources Ltd is applying to reopen the La Sal II mine in Lisbon Valley, Utah, bought in 2010 from Homestake with about 1000 tU. It is about 90 km from Energy Fuels' White Mesa mill, and a two-year toll milling agreement was signed in January 2013. As part of the 2016 deal with URI, Laramide agreed to sell La Sal II to URI for $4 million.

Laramide also has the La Jara Mesa project in the Grants mineral belt of New Mexico, with 4000 tU resource (NI 43-101 compliant, two-thirds 'indicated').

In January 2017 Mesa Exploration acquired the Noah uranium prospect in Utah's Lisbon Valley mining district on the Colorado Plateau, 96 km north of the White Mesa mill.

In Virginia, Virginia Uranium Inc, in association with Virginia Energy Resources Inc, has a proposal to mine the Coles Hill uranium deposit in Pittsylvania county which has 3260 tU as measured resource and 42,800 tU as indicated resource at 0.05 %U (NI 43-101 compliant). An associated conventional mill would be near Chatham. A detailed state review reported on the project, but the Governor at the end of 2013 announced that he would veto any enabling legislation. This was unsuccessfully appealed, with the companies asking the courts either to order the Commonwealth of Virginia to permit the plaintiffs to exercise their right, under Virginia's constitution, to mine the uranium situated on their property, or to provide compensation for the "full value" of the mineral resource – $6 billion.

In Texas, Texas Rare Earth Resources Corp has signed an agreement with Areva to take up to 116 tU per year by-product uranium from its Round Top heavy rare earth project in Hudspeth County. About 37,000 tU is identified in all classes of REE resources there.

US in situ leach (ISL) uranium mines and production facilities

	ISL mines	Mill	Status	Annual capacity
Uranium One	Willow Creek/Christiansen Ranch, WY	Irigaray, WY	Operating	500 tU
	Moore Ranch, WY	Irigaray, WY	Licensed but suspended	190 tU, 770 tU
	Jab, Antelope, WY	Irigaray, WY	Developing	
EFRC (Uranerz Energy)	Nichols Ranch, Hank, Jane Dough, WY	Smith Ranch - Highland, WY	Operating from 2014	300 tU initially, 770 tU
EFRC (Mestena Uranium)	Alta Mesa, TX	Alta Mesa, TX	Operating to 2013	578 tU
Ur-Energy	Lost Creek, WY	Lost Creek, WY	Operating from 2013, standby	770 tU
Cameco Resources Inc	Smith Ranch - Highland, WY	Smith Ranch - Highland, WY	Operating	2100 tU
Cameco Resources	Crow Butte, NE	Crow Butte, NE	Operating	385 tU
Uranium Resources Inc (URI)	Rosita & Kingsville Dome, TX	Kingsville Dome, TX	Operating in 2008, but closed mid-2009	300 tU
Hydro Resources Inc (URI subsidiary) sold to Laramide Resources	Church Rock & Crownpoint, NM		Partially licensed	385 tU
Uranium Energy Corp, former: AUC/Bayswater	Reno Creek, WY	Reno Creek, WY	Licensed	330 tU, then up to 770 tU
Uranium Energy Corp	La Palangana, south TX	Hobson, TX	Standby	385 tU
	Goliad, Burke Hollow, TX	Hobson, TX	Goliad approved	385 tU
Peninsula/Strata	Lance, WY	Ross	Started operation Q1 2016	150 tU
Azarga Uranium	Dewey-Burdock, SD		Licensing deferred	385 tU
Total capacity				8053 tU

US hard rock uranium mines and mills

	Mine	Mill	Status	Annual capacity
EFRC	Arizona 1, Pinenut, Canyon, Wate, AZ	White Mesa, UT	Arizona1 operated 2009-14, Pinenut operated 2014-16, others on hold	
EFRC	La Sal, Energy Queen, Daneros, Whirlwind, CO-UT	White Mesa, UT	Mines on standby, Pinon Ridge, CO mill licensed but on hold	
EFRC	Roca Honda, NM	White Mesa, UT	Planned	
EFRC	Sheep Mtn & Gas Hills, WY	Whie Mesa, UT	Planned	
EFRC	Henry Mtns, UT	White Mesa, UT	Development on hold	
EFRC		White Mesa, UT	Operating, but closing temporarily 2015	3000 tU
Western Uranium	Sunday complex, CO Hansen-Taylor Ranch, CO	Pinon Ridge, CO	Licensed but on hold	
Cotter Corp		Canon City, CO	Standby, refurbish plan	
Rio Tinto		Sweetwater, WY	Standby	
Anfield		Shootaring Canyon, UT	Standby	

Legacy environmental issues

Uranium mining was a major activity in the late 1940s and into the 1950s, when the focus was on national security rather than environmental protection. There was little regulation or oversight of facilities, and tailings were put in impoundments without liners, giving rise to groundwater contamination.

There was a considerable legacy of pollution from abandoned uranium mines and treatment plants, most dating from the 1950s, and which was addressed in the 1980s. For instance, the Uravan mill site on the San Miguel River in Colorado was designated a Superfund site and was cleaned up between 1987 and 2007 at a cost of over $120 million. Historic mining and milling at Uravan included the production of radium, vanadium and uranium, leaving radioactive residues from the early 1900s through to the mid-1980s. From the time Uravan mill began operating in the 1920s until it was shut down, it processed over ten million tonnes of uranium-vanadium ore, giving rise to a similar amount of uncontained tailings, and 1,440 megalitres of liquid wastes were treated in the site rehabilitation program.

The Schwartzwalder mine west of Denver, Colorado, was once the largest underground uranium mine in USA. It has been polluting Ralston Creek feeding the city's water supply and is now subject to bacterial bioremediation by Cotter Corp.

In 2015, the US Department of Justice announced that $13.2 million in federal funding will be placed into a trust to pay for evaluations of abandoned uranium mines across Navajo lands in Arizona, New Mexico, and Utah. This will expedite the cleanup of 16 mines seen as the most significant hazards. The funding is part of an ongoing multi-agency federal initiative to address legacy issues connected with historic uranium mining across the Navajo Nation which produced four million tonnes of uranium ore between 1944 and 1986.

In 2017 the NRC ordered Homestake Mining to undertake groundwater remediation at the site of a mill which operated near Grants in New Mexico from 1958 to 1990. In 1975 it was discovered that seepage from 22 million tonnes of tailings in two impoundments had contaminated groundwater aquifers, and a groundwater protection

plan was implemented from 1977. The site is also under the oversight of the US Environmental Protection Agency (EPA) through the Superfund program. Homestake will submit a revised groundwater program to the NRC by the end of 2018.

Further Information

References

1. U.S. Uranium Mine Production and Number of Mines and Sources, US Energy Information Administration, Domestic Uranium Production Report (annual) [Back]

General sources

US Energy Information Administration (www.eia.doe.gov)
Company reports

WORLD NUCLEAR ASSOCIATION

Australia's Uranium

(Updated July 2017)

- **Australia's uranium has been mined since 1954, and three mines are currently operating. More are planned.**
- **Australia's known uranium resources are the world's largest – almost one-third of the world total.**
- **In 2016 Australia produced 7447 tonnes of U_3O_8 (6315 tU). It is the world's third-ranking producer, behind Kazakhstan and Canada. All production is exported. Uranium comprises about one-quarter of energy exports.**
- **Australia uses no nuclear power, but with high reliance on coal any likely carbon constraints on electricity generation will make it a strong possibility.**
- **In May 2016 the South Australian government's royal commission on the nuclear fuel cycle reported. Its main recommendation was for an international high-level nuclear waste repository, though this was not accepted.**

The Australian economy is unique in the OECD in that about 20% of GDP is accounted for by mining and mining services (in 2012). Uranium is a small part of this economically, but in energy terms, uranium (4200 PJ in 2015-16) comprises about one-quarter of energy exports.

In the 1930s ores were mined at Radium Hill and Mount Painter in SA to recover radium for medical purposes. As a result a few hundred kilograms of uranium were also produced.

Uranium ores as such were mined and treated in Australia initially from the 1950s until 1971. Radium Hill, SA, Rum Jungle, NT, and Mary Kathleen, Queensland, were the largest producers of uranium (as yellowcake). Production ceased either when ore reserves were exhausted or contracts were filled. Sales were to supply material primarily intended for USA and UK weapons programs at that time. However, much of it was used for electricity production.

The development of civil nuclear power stimulated a second wave of exploration activity in the late 1960s. A total of some 60 uranium deposits were identified from the 1950s through to the late 1970s, many by big companies with big budgets. (Since then only two significant new ones have been found: Kintyre and Beverley Four Mile. The minor exploration boom 2002-07 was driven by small companies focused on proving up known deposits.)

Mary Kathleen began recommissioning its mine and mill in 1974. Other developments were deferred pending the findings of the Ranger Uranium Environmental Inquiry, and its decision in the light of these. Mary Kathleen's second production phase was1976 to the end of 1982.

The Commonwealth Government announced in 1977 that new uranium mining was to proceed, commencing with the Ranger project in the Northern Territory. This mine opened in 1981. In 1979, Queensland Mines opened Nabarlek in the same region of Northern Territory. The orebody was mined out in one dry season and the ore stockpiled for treatment from 1980. The mine site is now rehabilitated.

A brief history of Australian uranium mining is appended. See also Former Australian Uranium Mines appendix.

Australian Uranium Production and Exports

	Calendar year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016

	Calendar year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Production	tonnes U_3O_8	11217	8954	10145	9941	9413	6958	7056	8244	7488	5897	6668	7447
	Tonnes U	9512	7593	8603	8430	7982	5900	5983	6991	6350	5000	5654	6315
Exports	tonnes U_3O_8	12360	8660	10232	9663	9706	6888	6628	8116	7317	5669	6969	7679
	Tonnes U	10481	7344	8676	8194	8230	5841	6170	6882	6205	4807	5909	6511
	A$ million FOB	573	529	881	749	1116	608	586	776	704	504	802	715
Export value*	A$/kg U_3O_8	46.36	61.06	86.11	77.54	114.9	88.3	88.4	95.6	96.2	88.9	115.1	93.1

Source: Companies, DRET, DIIS

* average $A from declared net FOB estimates

Recent Production from Individual Mines

tonnes U_3O_8

	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16
Ranger	5273	5678	4262	2677	3284	4313	1113	2044	2208
Olympic Dam	4115	3974	2258	4012	3853	4064	3988	3144	4363
Beverley	707	626	630	347	413	453	188	0	0
Four Mile						0	186	922	1615
Honeymoon				0	151	124	37	0	0
total	10095	10278	7150	7036	7701	8954	5512	6110	8186

Calendar year 2011 U_3O_8 production: 2641 t from Ranger, 3954 t from Olympic Dam, 416 t from Beverley, 45 t from Honeymoon, total 7056 tonnes (5983 tU)
Calendar year 2012 U_3O_8 production: 3710 t from Ranger, 3992.5 t from Olympic Dam, 386.7 t from Beverley, 154.6 t from Honeymoon, total 8244 tonnes (6990.6 tU)
Calendar year 2013 U_3O_8 production: 2960 t from Ranger, 4008.7 t from Olympic Dam, 407.4 t from Beverley, 112 t from Honeymoon, total 7488 tonnes (6349.6 tU)
Calendar year 2014 U_3O_8 production: 1165 t from Ranger, 3952 t from Olympic Dam, 24.7 t from Beverley, 755 t from Four Mile, total 5897 tonnes (5000 tU)
Calendar year 2015 U_3O_8 production: 2005 t from Ranger, 3728 t from Olympic Dam (corrected mid-2016), 935 t from Four Mile, total 6668 tonnes (5654 tU)
Calendar year 2016 U_3O_8 production: 2351 t from Ranger, 3813 t from Olympic Dam, 100 t from Beverley, 1183 t from Four Mile, total 7447 tonnes (6315 tU)

Operating Mines

The **Ranger mine** and associated town of Jabiru is about 230 kilometres east of Darwin, in the Northern Territory, surrounded by the Kakadu National Park, a major tourist attraction. The mine opened in 1981 at a production rate of approximately 3300 tonnes per year of uranium oxide and has since been expanded to 5500 t/yr capacity. Mining of the second pit was 1997 to 2012, and this is now being backfilled. Treatment is conventional acid leach. Any future development will be underground, and application was made for approval of this in January 2013. Substantial development was undertaken to mine the Ranger Deeps, and in June 2015 ERA announced that it will defer proceeding further with development of the underground mine to access 27,650 tonnes of uranium, after spending A$ 177 million on the project. This is due both to slow recovery in the uranium market and the

requirement to cease operations under the present Ranger Authority, which expires in 2021. Negotiations are exploring the potential to extend the deadline. Ranger is owned by Energy Resources of Australia Ltd (ERA), a 68.39% subsidiary of Rio Tinto.

During 1988 the **Olympic Dam** project, then a joint venture of Western Mining Corporation and BP Minerals, commenced operations about 560 km north of Adelaide, in an arid part of South Australia. The massive deposit is underground, some 350 metres below the surface, and is the largest known uranium orebody in the world. The large underground mine produces copper, with gold and uranium as major by-products. Annual production capacity for uranium oxide has been expanded from 1800 to 4600 tonnes U_3O_8. It is now owned by BHP Billiton, following its 2005 takeover of WMC Resources. There were plans to greatly increase the mine's size and output, by accessing the orebody with a huge open pit, about 4.1 x 3.5 km and 1000m deep,but since 2015 only underground development is planned. (Further details below.)

About 80% of the uranium is recovered in conventional acid leach of the flotation tailings from copper recovery. Most of the remaining 20% is from acid leach of the copper concentrate, but that concentrate then still contains up to 0.15% uranium. Hence the copper must be smelted at site, since selling it to overseas smelters would create both processing and safeguards complications for the smelter operator. This could change as part of a major envisaged expansion.

Both Ranger and the now-closed and rehabilitated Nabarlek mines are on aboriginal land in the Alligator Rivers region of the Northern Territory. Aboriginal people receive royalties of 4.25% on sales of uranium from Northern Territory mines. The total received simply from Ranger is now over $207 million, and $14 million came from Nabarlek.

The Olympic Dam mine is on formerly pastoral land in the middle of South Australia. A town to accommodate 3500 people was built at Roxby Downs to service the mine. The 18,000 ha mine lease is managed as a nature reserve.

The small **Beverley** mine in South Australia started operation late in 2000, 520 kilometres north of Adelaide, on the plains north-west of Lake Frome. It was Australia's first in situ leach (ISL) mine, accessing a palaeochannel deposit in sand in a saline aquifer. It was licensed to produce 1180 t/yr U_3O_8 (1000 tU), and reached this level in 2004, though production has declined since. It is owned and operated by Heathgate Resources Pty Ltd, an associate of General Atomics in the USA. In December 2010 the company received government approval to mine the Beverley North deposits, and now almost all production through the Beverley plant comes from this north orebody which is contiguous with the Four Mile deposits. Mining of Beverley ceased at the end of 2013, and of Beverley North early in 2014, though 100 tonnes was reported for the second half of 2016.

The **Four Mile** leases are contiguous with Beverley, and mining the east orebody by ISL commenced in April 2014. Resources are split between the west and the east orebodies, and the northeast orebody is also prospective. Uranium recovery is through Heathgate's Pannikin satellite ion exchange plant then trucking the loaded resin to the main Beverley plant for stripping (elution) and precipitation, as is done at two US mines. Alliance Resources Ltd is a 25% free-carried joint venture partner after Heathgate's Quasar subsidiary farmed in to the project. Production is at about 1000 t U_3O_8 per year.

The **Honeymoon** ISL mine in South Australia commenced operation in 2011. The owners received government approval to proceed with ISL mine development in November 2001 but reassessed its ore reserves and Uranium One, based in Toronto, finally moved to development in 2007. In 2008 Mitsui agreed to join the project as 49% joint venture partner, and a construction contract was then let. Operations were ramping up to 400 t/yr. In 2012 production was expected to be 275 tonnes U_3O_8, at $47/lb - three times the average cost of production in Kazakhstan. In fact it produced less. Mitsui largely funded the development and commissioning, but then withdrew from the project in 2012. In November 2013 Uranium One, by then owned by Russia's ARMZ, closed the mine and put it on care and maintenance until uranium prices improved. In September 2015 Boss Resources Ltd based in Perth agreed to buy Uranium One Australia which owned the mine.

For more detail of mines see appendix: *Australia's Uranium Mines*.

Uranium resources

On the basis of December 2012 data Australia has 29% of the world's uranium resources (under US$ 130/kg) – 1.7 million tonnes of uranium. Almost half of Australia's 1.174 million tonnes of reasonably assured resources of uranium in this price category were actually in the under $80/kg U category when this was last reported. The vast majority of Australia's uranium resources (to $130/kgU) are within five deposits: Olympic Dam (the world's largest known uranium deposit), Ranger, Jabiluka, Kintyre and Yeelirrie.

The world's Reasonably Assured plus Inferred Resources in the $130/kg category are tabulated in the Supply of Uranium information paper.

A review of Australia's uranium is provided in Australia's Uranium: Resources, Geology and Development of Deposits from Geoscience Australia.

Uranium resources at mines and major deposits
tonnes U_3O_8

Mine or deposit	Type	Reserves	Measured & Indicated Resources	Inferred Resources
Ranger	hard rock, most underground	8,081	44,883	11,087
Olympic Dam	hard rock, underground	305,150	1,555,100	1,012,800
Beverley	palaeochannel, ISL		?	?
Four Mile	palaeochannel, ISL		14,520	39,926
Honeymoon	palaeochannel, ISL		4,920	7,620

Mine or deposit	Type	Reserves	Measured & Indicated Resources	Inferred Resources
Jabiluka	hard tock, underground		82,945	54,162
Kintyre	hard rock		25,274	2,400
Yeelirrie	calcrete		57,760	0
Wiluna	calcrete		27,400	9,600
Mulga Rock	palaeochannel and lignite		20,650	20,000
Samphire	palaeochannel and basement granite		0	21,000
Valhalla	hard rock		24,765	5,860

Resources are additional to reserves.

Prospective mines and expansion

The Jabiluka uranium deposit in the Northern Territory was discovered in 1971-73, 20 kilometres north of Ranger. It is surrounded by the Kakadu National Park, but the mine lease area is excluded from the National Park and adjoins the Ranger lease. It has resources of over 130 000 tonnes of uranium oxide, and is one of the world's larger high-grade uranium deposits. A mining lease was granted in 1982 but development was stalled due to disagreements with the Aboriginal traditional owners. Then with the Australian Labor Party coming to power in the 1983 federal election, Commonwealth approval was withdrawn and development ceased. In 1991 Energy Resources of Australia (ERA), the operator of the adjacent Ranger mine, bought the Jabiluka lease from Pancontinental for A $125 million.

Following the 1996 change of government and further approvals, development of the underground mine proceeded with an 1150 metre access decline and a further 700 metres of excavation around the orebody. However, mining was deferred until agreement could be reached regarding treatment of Jabiluka ore at the Ranger mill. ERA (whose parent company is Rio Tinto) will not proceed with the mine until there is agreement from the local Mirrar Aboriginal people.

For Olympic Dam BHP Billiton undertook a major feasibility study on greatly expanding the mine, and in 2009 it released the 4600-page environmental impact statement for the project. This was approved by state and federal governments in October 2011. The plan was to develop a large open pit with associated infrastructure over 11 years and lift uranium production to 19,000 tonnes U_3O_8 per year. The open pit would mean that up to 98% of the ore is mined rather than much less of it. Most of the uranium would be separated at the mine, but up to 2000 t/yr would be exported in copper concentrates, requiring a smelter for these in China or Japan which is subject to international nuclear safeguards. New infrastructure would include a 280 ML/day desalination plant on Spencer Gulf, supplying 200 ML/day to the operation, and 650 MWe increase in power supply. The present underground mining would continue in the narrow northern part of the orebody. However, in August 2012 the company said that it would investigate a new and less-costly design for its planned open-pit expansion, which meant it could not approve the project in time to meet a government deadline in December. In November 2012 the state government granted a four-year extension, conditional on the company spending $650 million on pre-project research on heap leaching and on community work.

In November 2014, in a general announcement about productivity, BHP Billiton flagged a 27% increase in copper production at Olympic Dam from 2018, and a doubling from that level subsequently by “a low-risk underground expansion with significantly lower capital intensity than the previous open cut design. This has the potential to deliver over 450,000 tonnes of copper production a year at first quartile C1 costs by the middle of next decade”. The uranium implications were not mentioned, but assuming the same ore as today, it would mean about 5000 t U_3O_8 (4200 tU) per year from 2018 and some 9400 t U_3O_8 (8000 tU) per year in mid-2020s. In July 2016 the company confirmed that it would now focus on underground development only and not pursue the earlier open pit plan. Its increased copper production would involve a corresponding increase in uranium production.

Cameco and Mitsubishi (70:30%) bought the **Kintyre** deposit in WA in 2008 from Rio Tinto for uS$ 495 million. Cameco initially envisaged starting mine construction in 2013 and operation in 2015, to produce 2700 to 3600 t U_3O_8 per year for 15 years. In mid-2012 Cameco put the project on hold pending firmer uranium prices or lower development costs. State and federal environmental approvals were given in 2015.

BHP Billiton applied to bring its **Yeelirrie**, WA, deposit into production and projected 2000 t/yr U_3O_8 production from 2014, though in February 2010 approval was sought for production at 3500 t/yr. However, in 2011 the project was wound down due to high treatment costs and in 2012 it was sold to Cameco for US$ 340 million. In November 2014 Cameco requested the WA EPA to cancel the earlier environmental application, and submit a new one involving production at 7500 t U_3O_8 per year, and to assess the application under new 2012 EPA procedures. In January 2017 the state government approved development.

Toro Energy is well advanced with plans to produce 900 t/yr U_3O_8 from its **Wiluna** project, comprising the shallow Lake Way and Centipede-Millipede deposits and the nearby Lake Maitland deposit in WA, from 2016. In January 2017 the state government approved development, but the company awaits higher uranium prices.

Vimy Resources is developing the **Mulga Rock** deposits in WA to produce 1300 t/yr U_3O_8, with progressive open pits to 32 metres depth. In December 2016 the state government approved development and federal government approval followed in March 2017.

The largest prospective Queensland mine is Paladin's **Valhalla**, 40 km north of Mount Isa. This is a major deposit but was stalled to 2012 by state government policies.

There has been increasing foreign equity in Australian uranium deposits. As well as the Honeymoon, Kintyre and Yeelirrie projects above, in February 2009 Mega Uranium sold 35% of the Lake Maitland project to the Itochu Corporation (10% of Japanese share) and Japan Australia Uranium Resources Development Co. Ltd. (JAURD), acting on behalf of Kansai Electric Power Company (50%), Kyushu Electric Power Company (25%) and Shikoku Electric Power Company (15%) for US$ 49 million. In 2006 Sinosteel bought 60% of Pepinini's Curnamona project for A$ 31 million, and in 2009 China Guangdong NPC bought 70% of Energy Metals' Bigrlyi project for A$ 83.6 million. Both are early-stage exploration ventures.

For more detail of mine prospects see paper on Australia's Uranium Deposits and Prospective Mines.

Despite restrictive state government policies and perhaps in anticipation of their disappearance, uranium exploration gathered pace during 2006, with more than 200 companies professing an interest, compared with 34 the previous year, and A$ 80 million being spent. Expenditure then more than doubled, to A$ 182 million in 2007, A$ 227 million in 2008, A$ 180 million in 2009 and A$ 190 million in 2011. It then declined abruptly to A$ 98 million in 2012.

Uranium exploration has been illegal in Victoria and New South Wales, and remains so in Victoria. Uranium mining is being reinstated in Queensland after a few years' break.

Economic benefits of mining uranium

About 1200 people are employed in uranium mining, at least 500 in uranium exploration, and 60 jobs are in regulation of uranium mining.

Uranium mines generate about A$ 21 million in royalties each year (in 2005: Ranger $13.1 million, Beverley $1.0 million and Olympic Dam $6.9 million attributable to uranium). Corporate taxes amount to over $42 million per year.

Uranium exports from Australia

Australian production is all exported, and over the six years has averaged over 8600 t/yr U_3O_8, and in 2012 provided 12% of world uranium supply from mines. Uranium comprises about 35% of the country's energy exports (4150 PJ av) in thermal terms.

close. The new plant will more fully utilise the OPAL reactor's capacity. The investment also covers building an industrial-scale plant for Synroc waste form to immobilise the intermediate-level wastes from Mo-99 production. ANSTO hopes that the Synroc technology "will become the benchmark for waste treatment in the production of Mo-99 radiopharmaceuticals."

See further: Australian Research Reactors, as Appendix to this paper, and Synroc Wasteform appendix to the information paper on *Treatment and Conditioning of Nuclear Wastes*.

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Appendix

A brief history of Australian uranium mining

The existence of uranium deposits in Australia has been known since the 1890s. Some uranium ores were mined in the 1930s at Radium Hill and Mount Painter, South Australia, to recover minute amounts of radium for medical purposes. Some uranium was also recovered and used as a bright yellow pigment in glass and ceramics.

Following requests from the British and United States governments, systematic exploration for uranium began in 1944. In 1948 the Commonwealth Government offered tax-free rewards for the discovery of uranium orebodies. As a result, uranium was discovered by prospectors at Rum Jungle in 1949, and in the South Alligator River region (1953) of the Northern Territory, then at Mary Kathleen (1954) and Westmoreland (1956) in north west Queensland.

In 1952 a decision was taken to mine Rum Jungle, NT and it opened in 1954 as a Commonwealth Government enterprise. Radium Hill, SA was reopened in 1954 as a uranium mine. Mining began at Mary Kathleen, Qld in 1958 and in the South Alligator region, NT in 1959. Production at most mines ceased by 1964 and Rum Jungle closed in 1971, either when ore reserves were exhausted or contracts were filled. Sales of some 7730 tonnes of uranium from these operations were to supply material primarily intended for USA and UK weapons programs at that time. However much of it was used in civil power production.

The development of nuclear power stimulated a second wave of exploration activity in the late 1960s. In the Northern Territory, Ranger was discovered in 1969, Nabarlek and Koongarra in 1970, and Jabiluka in 1971. New sales contracts (for electric power generation) were made by Mary Kathleen Uranium Ltd., Queensland Mines Ltd. (for Nabarlek), and Ranger Uranium Mines Pty. Ltd., in the years 1970-72.

Successive governments (both Liberal Coalition and Labor) approved these, and Mary Kathleen began recommissioning its mine and mill in 1974. Consideration by the Commonwealth Government of additional sales contracts was deferred pending the findings of the Ranger Uranium Environmental Inquiry, and its decision in the light of these. Mary Kathleen recommenced production of uranium oxide in 1976, after the Commonwealth Government had taken up a 42% share of the company.

The Commonwealth Government announced in 1977 that new uranium mining was to proceed, commencing with the Ranger project in the Northern Territory. In 1979 it decided to sell its interest in Ranger, and as a result Energy Resources of Australia Ltd was set up to own and operate the mine. The mine opened in 1981, producing 2800 t/yr of uranium, sold to utilities in several countries. Production over three years to mid 2002 averaged 3533 t/yr of uranium.

In 1980, Queensland Mines opened Nabarlek in the same region of Northern Territory. The orebody was mined out in one dry season and the ore stockpiled for treatment from 1980. A total of 10,858 tonnes of uranium oxide were produced and sold to Japan, Finland and France, over 1981-88. The mine site is now rehabilitated.

At the end of 1982 Mary Kathleen in Queensland had depleted its ore and finally closed down after 4802 tonnes of uranium oxide had been produced in its second phase of operation. This then became the site of Australia's first major rehabilitation project on a uranium mine site, which was completed at the end of 1985. A Rum Jungle Rehabilitation project also took place in the 1980s.

Australian Labor Party (ALP) policy on uranium mining has varied over four decades. The 1971 Platform, on which the Whitlam Government was elected in 1972, committed the party to working towards the establishment of a domestic uranium enrichment and nuclear power sector. But after losing government in 1975, pressure grew in the Labor Party for a strong stance against uranium mining and export, as a counterpoint to Liberal Coalition policies to expedite uranium mining and export. An anti-nuclear movement gained strength and campaigned to end Australian uranium mining.

The 1977 ALP National Conference adopted a new policy. Community concerns with the threat of nuclear war were to be allayed by ending uranium mining and ceasing Australia's contribution to the nuclear fuel cycle. The change committed a future Labor government to declare a moratorium on uranium mining and treatment and to repudiating any commitments to mining, processing or export made by a non-Labor government. The policy made a strong statement and was seen to provide moral leadership.

By the time of the 1982 ALP National Conference, many in the Labor Party were troubled about how an incoming Labor Government would implement the party's moratorium policy. There was concern that the repudiation of contracts would raise issues of sovereign risk and would expose a Labor government to compensation liabilities. An amendment to the ALP Platform in 1982 sought a compromise between the positions of those who wanted to shut the industry down and those who felt that doing so was neither possible nor in the national interest. It committed Labor to a policy on uranium mining which was a classic political compromise, the core of which endured as Labor policy for 25 years. The policy was designed to prevent new uranium mines; limit Australia's uranium production with a view to the eventual phasing out of mining altogether; and provide moral leadership in ending the nuclear industry.

However, in a concession to South Australia, it also said that a Labor government would "consider applications for the export of uranium mined incidentally to the mining of other minerals on a case by case basis". This was the Roxby Downs amendment, which would allow export of uranium from Olympic Dam - a major copper and uranium deposit. So the 1982 anti-uranium policy actually authorised the development of the world's largest uranium mine!

In the 1983 federal election the ALP won office. The 1984 ALP National Conference then dropped the language of moratorium, repudiation of contracts and phase-out from the Platform. For the first time the three-mines-policy was delineated by naming Nabarlek, Ranger and Roxby Downs (Olympic Dam) as the only projects from which exports would be permitted. Provisional approvals for marketing from other prospective uranium mines were cancelled.

The naming of specific mines was later deleted from the Labor Platform in the light of the fact that Nabarlek ceased production in 1988 and under a (conservative) Coalition government Beverley started up in 2000. The ALP policy then only allowed exports from existing mines and prevented the establishment of new ones. This endured as a "no new mines" policy through a change of government in 1996 until 2007, when it was abandoned as ineffective and likely to be electorally negative due to changed public opinion arising from global warming concerns. Opposition to uranium mining was then left to state ALP branches and governments. This continued in WA and Queensland until changes of government in 2008 and 2012 respectively. (NSW and Victoria have legislation banning uranium exploration and mining, which has not been repealed by conservative governments.) A fourth mine, Honeymoon, started up in South Australia in 2011.

Adapted from Senator Chris Evans speech 23/3/07 to Labor Business Roundtable, Perth.

During 1988 the Olympic Dam project commenced operations. This is a large underground mine at Roxby Downs, South Australia, producing copper, with uranium and gold as by-products. Annual production of uranium started at some 1300 tonnes, with sales to Sweden, UK, South Korea and Japan. After a A$ 1.9 billion expansion project, production increased to over 4000 tonnes uranium per year by mid 2001. In 2005 it was taken over by BHP Billiton.

Beverley, the first Australian in situ leach (ISL) mine started up in 2001 and closed early in 2014. Another ISL mine, Honeymoon, came on line in 2011 and closed in 2013. Production from Four Mile started in 2014, using a satellite plant to capture the uranium from ISL and the Beverley plant for final product recovery. Beverley and Honeymoon may resume production with increased uranium prices.

Both Ranger and Nabarlek mines are on aboriginal land in the Alligator Rivers region of the Northern Territory, close to the Kakadu National Park. In fact the Ranger and two other leases are surrounded by the National Park but were deliberately excluded from it when the park was established. Ranger is served by the township of Jabiru, constructed largely for that purpose. Nabarlek employees were based in Darwin and commuted by air.

See also: Former Australian Uranium Mines paper.

Australia's Uranium Mines

Appendix to Australia's Uranium.

(Updated October 2017)

There are three operating uranium mines in Australia: Ranger in Northern Territory, Olympic Dam in South Australia, and Beverley with Four Mile in South Australia. Four Mile has final processing through the Beverley plant. Honeymoon was shut down in 2013 pending improved uranium prices, and the main Beverley (and North Beverley) wellfields were also shut down soon after that, until late 2016. There are plans to bring Honeymoon back into production.

See also companion paper on Australia's Uranium Deposits and Prospective Mines.

Recent Production from Australian Uranium Mines
(tonnes of U_3O_8)

	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
Ranger	5256	5273	5678	4262	2677	3284	4313	1113	2044	2208	2315
Olympic Dam	3474	4115	3974	2258	4012	3853	4064	3988	3144	4363	3661
Beverley	847	707	626	630	347	413	453	188	0	0	
Four Mile							0	186	922	1615	
Honeymoon	0	0	0	0	0	151	124	37	0	0	0
Total	9577	10095	10278	7150	7036	7701	8954	5512	6110	8186	

Calendar year 2011 U_3O_8 production: 2641 t from Ranger, 3954 t from Olympic Dam, 416 t from Beverley, 45.4 t from Honeymoon, total 7056 tonnes (5983 tU).

Calendar year 2012 U_3O_8 production: 3710 t from Ranger, 3992.5 t from Olympic Dam, 386.7 t from Beverley, 154.6 t from Honeymoon, total 8244 tonnes (6990.6 tU).

Calendar year 2013 U_3O_8 production: 2960 t from Ranger, 4008.7 t from Olympic Dam, 407.4 t from Beverley, 112 t from Honeymoon, total 7488 tonnes (6350 tU).

Calendar year 2014 U_3O_8 production: 1165 t from Ranger, 3952 t from Olympic Dam, 24.7 t from Beverley, 755 t from Four Mile, total 5897 tonnes (5000 tU).

Calendar year 2015 U_3O_8 production: 2005 t from Ranger, 3728 t from Olympic Dam, 935 t from Four Mile, total 6668 tonnes (5654 tU).

Calendar year 2016 U_3O_8 production: 2351 t from Ranger, 3813 t from Olympic Dam, 1183 t from Four Mile, 100 t from Beverley, total 7447 tonnes (6315 tU).

Ranger

The Ranger mine and associated town of Jabiru is about 230 kilometres east of Darwin, surrounded by the Kakadu National Park, a major tourist attraction. This is a monsoonal part of Australia, with pronounced wet season from December to April. The first two orebodies are now mined out and work is under way to develop an underground mine, though in the longer term the Jabiluka orebody, 20 km away on a contiguous lease, is a more significant prospect (see Uranium Deposits paper). The mining authority runs to January 2021, 40 years from commencement.

History:

In 1969 the Ranger orebody was discovered by a Joint Venture of Peko Wallsend Operations Ltd (Peko) and The Electrolytic Zinc Company of Australia Limited (EZ). In 1974 an agreement set up a joint venture consisting of Peko, EZ and the Australian Atomic Energy Commission (AAEC).

In 1978, following a wide ranging public inquiry (the Ranger Uranium Environmental Inquiry) and publication of its two reports (the Fox reports), agreement to mine was reached between the Commonwealth Government and the Northern Land Council, acting on behalf of the traditional Aboriginal land owners. The terms of the joint venture were then finalised and Ranger Uranium Mines Pty Ltd was appointed as manager of the project.

In August 1979 the Commonwealth Government announced its intention to sell its interest in the Ranger project. As a result of this, Energy Resources of Australia Ltd (ERA) was set up with 25% equity holding by overseas customers. In establishing the company in 1980 the AAEC interest was bought out for $125 million (plus project costs) and Peko and EZ became the major shareholders. Several customers held 25% of the equity in non-tradable shares. Ranger Uranium Mines Pty Ltd became a subsidiary of ERA. During 1987-8 EZ's interest in ERA was taken

over by North Broken Hill Holdings Ltd and that company merged with Peko. Consequently ERA became a 68% subsidiary of North Limited, and this holding was taken over by Rio Tinto Ltd in 2000. In 1998 Cameco took over Uranerz, eventually giving it 6.69% of ERA, and Cogema took over other customer shares, giving it (now Areva) 7.76%.

Late in 2005 there was a rearrangement of ERA shares which meant that Cameco, Cogema and a holding company (JAURD) representing Japanese utilities lost their special unlisted status and their shares became tradable. The three companies then sold their shares, raising the level of public shareholding to 31.61%.

Production and sales

The mine started operating in 1980. Full production was in October 1981 at a rate of about 3300 tonnes per year of uranium oxide concentrate. Ranger #1 open pit was mined out over 1980-94, then pit #3 over 1997-2012. The run of mine stockpile then comprised 1.4 Mt of ore at average 0.165% U_3O_8, which was treated by mid-2013. With other surface stockpiled ore averaging 0.12% U_3O_8 there is enough to last to 2020 if market conditions are favourable, or at least to 2016 when underground mining is planned to commence. However, annual production diminished from 2012 as progressively lower grade material is processed at a constant mill rate of about 2.4 Mt/yr. It is envisaged the lowest grade material might be blended with high-grade ore from underground from 2016. Uranium recovery ranges up to 93%.

Aerial view of Ranger Mine and Plant

Until 1990 all ERA sales of uranium concentrate were from Ranger production. Over several years the spot price of uranium concentrates was below the cost of production at Ranger, which made it advantageous over 1990-97 for ERA to purchase supplies from third parties. In 1994 the level of 1510 tonnes just exceeded that year's mine production. Further purchases were made 2001-05. The third party concentrates concerned mostly came from Kazakhstan. In 2011 ERA purchased 2126 t U_3O_8 to meet its sales commitments, including 1636 tonnes for actual 2011 sales. In 2012 about 500 t was purchased (387 t to end June). ERA sales are mostly under contracts with customers who are prepared to pay a price premium for long-term security of supply.

In 2013 production at Ranger was 2690 tonnes of U_3O_8 (2510 tU), curtailed due to closure of the treatment plant after a leach tank failed in December. (NB ERA reports drummed production, whereas Rio Tinto reports Ranger figures on a slightly different basis.) Operations resumed in June 2014, but no product was drummed in that half year, and only 1165 t U_3O_8 (988 tU) was produced in the full year. Mill head grade in 2014 was 0.11% with recovery 81.5%. In 2015, 2005 t U_3O_8 was produced.

All ERA uranium oxide sales are to energy utilities in Japan, South Korea, China, UK, France, Germany, Spain, Sweden and the United States under international and bilateral safeguards regulations. ERA supplied about 5% of the world's uranium production in 2012. Asia is a particularly important market, with most of the company's premium priced contracts there supplied from Ranger.

In 2008 total energy consumption was 1457 TJ, for production of uranium 2264 PJ (@ 500 TJ/t used in conventional reactor), ie 0.064% of output. CO_2 equivalent greenhouse gas emissions were 155,0000 t.

Ranger treatment plant, with mine pit beyond

Process

Following crushing, the ore is ground and processed through a sulfuric acid leach to recover the uranium. The pregnant liquor is then separated from the barren tailings and in the solvent extraction plant the uranium is removed using kerosene with an amine as a solvent. The solvent is then stripped, using an ammonium sulphate solution and injected gaseous ammonia. Yellow ammonium diuranate is then precipitated from the loaded strip solution by raising the pH (increasing the alkalinity), and removed by centrifuge. In a furnace the diuranate is converted to uranium oxide product (U_3O_8).

Reserves & resources

The Ranger 1 orebody, which was mined out in December 1995, started off with 17 million tonnes of ore some of which is still stockpiled. The Ranger 3 nearby is slightly larger, and open pit mining of it took place over 1997 to 2012.

In 1991 ERA bought from Pancontinental Mining Ltd the richer Jabiluka orebody (briefly known as North Ranger), 20 km to the north of the processing plant and with a lease adjoining the Ranger lease. ERA was proposing initially to produce 1000 t/yr from Jabiluka concurrently with Ranger 3. The preferred option involved trucking the Jabiluka

ore to the existing Ranger mill, rather than setting up a new plant, tailings and waste water system to treat it on site as envisaged in an original EIS approved in 1979. However, all these plans are now superseded – see information page on Australia's Uranium Deposits and Prospective Mines.

Ranger Ore Reserves and Resources, 31/12/16

	Grade U_3O_8 (%)	Contained U_3O_8 (tonnes)
Ranger stockpile	0.081	8,081
Total reserves	0.081	8,081
Mineralised stockpile resources	0.04	12,113
Measured resources in situ (R3 Deeps)	0.27	10,134
Indicated resources in situ (R3 Deeps)	0.22	22,636
Inferred resources (R3 Deeps)	0.20	8,579
Total R3 Deeps resources	0.224	43,858
Total resources	0.11	55,971

Note: figures are based on a 0.02% cut off for open pit resources, and 0.11% for underground resources (Ranger 3 Deeps). Resources are additional to reserves. A large reduction in resources in 2012 was due to reclassifying in-situ low-grade ores from Mineral Resources to Mineralised Inventory as pit 3 is backfilled, sterilizing the large pit shell resource.

In the Ranger 3 Pit and Deeps the upper mine sequence consists of quartz-chlorite schists and the lower mine sequence is similar but with variable carbonate (dolomite, magnesite and calcite). The primary ore minerals have a fairly uniform uranium mineralogy with around 60% coffinite, 35% uraninite and 5% brannerite. In weathered and lateritic ores the dominant uranium mineralogy is the secondary mineral saleeite with lesser sklodowskite.

In the second half of 2008 a $44 million processing plant was commissioned to treat 1.6 million tonnes of stockpiled lateritic ore with too high a clay content to be used without this pre-treatment. Following initial treatment the treated ore is fed into the main plant, contributing 400 t/yr U_3O_8 production for seven years. A new $19 million radiometric ore sorter was commissioned at the same time, to upgrade low-grade ore and bring it to sufficient head grade to go through the mill. It will add about 1100 tonnes U_3O_8 to production over the life of the mine, and be essential for beneficiating carbonate ore from the lower mines sequence of the Ranger 3 Deeps.

A feasibility study into a major heap leach operation for 10 Mt/yr of low-grade ore showed the prospect of recovering up to 20,000 t U_3O_8 in total. Column leach trials were encouraging, yielding extractions of greater than 70% at low rates of acid consumption. The facility would consist of fully lined heaps of material about 5m high and covering about 60-70 ha. These will be built and removed on a regular cycle and the residues stored appropriately after leaching is completed. The acid leach solutions would be treated in a process similar to that used in the existing Ranger plant and recycled after the uranium is removed from the pregnant liquor. ERA applied for government (including environmental) approval for the project, which was expected to begin operation in 2014, but in August 2011 ERA announced that the plan was shelved due to high capital costs and uncertain stakeholder support. As a result, ore reserves of 7,100 tonnes of uranium oxide were reclassified as resources.

In 2006 the projected operating life of the Ranger plant was extended to 2020 due to an improvement in the market price enabling treatment of lower grade ores, and in 2007 a decision to extend the operating Ranger 3 open pit at a cost of $57 million meant that mining there continued to 2012. However, reassessment of the low-grade stockpile in 2011 resulted in downgrading reserves by 6100 t U_3O_8. The #3 pit is now being backfilled, and to mid-2014, 31 million tonnes of waste material had been moved there. Following that it is being used for tailings, and all the material in the tailings dam will eventually be transferred there, using a dredge to recover it.

Ranger 3 Deeps

By November 2008 ERA had defined the Ranger 3 Deeps mineralisation target in the range of 15 to 20 million tonnes, and this has been confirmed as containing 33,000 tonnes of uranium oxide (28,000 tU) reported in the figures above. The mineralised zone has a strike length so far identified of about 1.2 kilometres between 250 and 550 metres from the surface, immediately east of the pit, and remains open to the north. Following regulatory approval in 2011, ERA awarded a A$50 million contract to McMahon Holdings for establishing a boxcut near pit 3 and 2.2 km decline in preparation for its own further drilling program. The decline reached a depth of 500 metres, and was built to handle eventual production. Work began in May 2012 and it was completed at the end of 2014, on schedule and on budget.

In June 2012 ERA approved spending A$57 million on a pre-feasibility study of the project to 2014, including 16,000 m of drilling. In January 2013 ERA applied for environmental approval of the Ranger 3 Deeps exploration decline project. In total the company planned to spend A$120 million on the project, plus a $57 million prefeasibilty study, leading towards a decision to mine early in 2015. About half the tailings from the underground ore will be returned there, and the mine footprint will shrink from 68 ha for pit 3 to 2 ha for the decline. In October 2014 the company lodged a draft EIS for the mine project, targeting first production at the end of 2015.

In June 2014 the company announced an update of resources in Ranger 3 Deeps after two-thirds of the drilling program was completed. A total of 32 km of drilling had been undertaken, and the decline reached 2221 metres from the surface. Total resources were 33,770 tonnes U_3O_8 averaging 0.274% grade at 0.15% cut-off, two-thirds in the upper mine sequence and one-third in the lower, which has higher carbonate levels. The pre-feasibility study (PFS) was considered by the Board early in 2015, and in June the company announced that it would defer proceeding further with development. This is due both to slow recovery in the uranium market and the requirement to cease operations under the present Ranger Authority, which expires in January 2021. Negotiations are exploring the potential to extend the deadline. Majority owner Rio Tinto said it “does not support any further study or future development of Ranger 3 Deeps due to the project’s economic challenges.”

ERA had envisaged completing processing by Jan 2021 and completing $640 million site rehabilitation by 2026; these dates are not flexible, so prima facie would need to include all underground mining and treatment of any other ore (*e.g.* northern deposits on the Ranger lease).

In May 2016 ERA announced that a strategic review concluded that it would maximise cash flow from stockpiled ore reserves containing 10,383 t U_3O_8, and that it should preserve the option to develop the Ranger 3 Deeps project in the future by keeping the exploration decline and related infrastructure under care and maintenance at a cost of A$4 million per year. However, ERA stated: “Ranger 3 Deeps can only be viably developed with an extension to the current Ranger Authority which permits processing operations until January 2021. An amendment to the Atomic Energy Act of 1953 would be required to enable an application for an Authority extension.” Furthermore unless reactivation of Ranger 3 Deeps was before mid-2018, there would be a gap in production after exhaustion of stockpiled ore in 2020.

Occupational health & safety

Radiation doses received by employees are all well below recommended limits. The designated employees (most exposed to radiation) received an average dose of 1.3 millisieverts per year above natural background in 2008 compared with the recommended annual limit of 20 mSv averaged over 5 years. In first half of 2007 the maximum dose to any person was 3.9 mSv, hence less than 8 mSv/yr.

ERA’s occupational safety and health management systems are certified to AS4801. In 1994 ERA was the first Australian mine to be awarded a 5-star rating by the National Safety Council, putting it in the top 5% of all industry occupational health and safety performance.

Infrastructure

Along with building other infrastructure used by the public, the Company set up the town of Jabiru nearby. While it was initially envisaged that this would be solely a mining town, it has become an important regional centre for tourism and government services, including management of the National Park. Some 200 000 tourists visit the area each year.

Environmental management

ERA has been recognised for its world-class environmental management, achieving ISO 14001 certification in 2003.

Until 1996 tailings from the treatment plant were emplaced in an engineered dam on the lease. They were then deposited into the worked out #1 pit, and later to the tailings dam which was raised from RL 36 m to RL 60.5 m. No process or other contaminated water is released from the site, but concerns were raised about seepage from the tailings dam, and in 2009 the Supervising Scientist estimated this at 100 m3/day. Consequently the Gundjeihmi Aboriginal Corporation negotiated an independent hydrological review of the situation which resulted in many (79) more monitoring bores being established and a greatly improved seepage model. This will provide helpful data for the rehabilitation of the tailings area by 2026.

The Ranger mine is on a 7860 hectare lease which is surrounded by the World Heritage listed Kakadu National Park of 1.98 million hectares. About 500 hectares is actually disturbed by the mining and milling activities (0.025% of the total area).

Rainfall is monsoonal, with 700-2200 mm (average 1540 mm) falling in the wet season. The vegetation at Ranger is tropical open eucalypt forest, similar to much of the National Park.

The project area is leased from the Aboriginal traditional owners, title to the land being held by the Kakadu Land Trust. The Company contributes 4.25% of its gross sales revenue (the major part of its royalties of 5.5%) to NT aboriginal groups plus an annual rental of $200 000 for the use of the land. Ranger has paid a total of $345 million to aboriginal interests, including royalties, since the project began in 1980, in addition to jobs and community and social contributions. The royalty money is paid to the Commonwealth Government and then distributed to Northern Territory-based Aboriginal groups, including 30% to the Gundjeihmi Aboriginal Corporation (representing Traditional Owners), under the 1979 terms of the Commonwealth's Aboriginal Land Rights (NT) Act of 1976. Additional payments of over $7 million are on account of Jabiluka. The balance of royalty (1.25% of revenue) is paid to the NT government by the Commonwealth Government.

The company has a substantial environmental division, employing about 30 people and with an annual budget of nearly A $3 million. Part of this environmental effort is directed to land management issues of relevance not simply to Ranger, but to the surrounding National Park and World Heritage area. These include maintenance of biodiversity, fire management including control burning (which is very important and contentious in the region), terrestrial and aquatic weed control, feral animal control, mycorrhizal establishment, and rehabilitation of disturbed areas (including rock waste dumps, etc). Ranger is possibly the first mining operation deliberately to burn its own revegetated areas to assist the development of an appropriate vegetation community (Eucalypts and Grevilleas instead of Acacia dominance). Related issues being studied include artificial wetland filters, soil formation from waste rock, and hydrology.

Among Ranger's long term research priorities are projects which are relevant to eventual use of the land by its aboriginal owners.

ERA's success in environmental management has given rise to a consultancy, Earth Water Life Sciences, which gained significant business based on Ranger's environmental reputation.

Notwithstanding any results that may come from the ongoing exploration program, the company developed its plans for mine closure early in its history. A mine closure model has been prepared, and circulated to stakeholders, resulting in an estimate of the technical, environmental, social and other costs, through to final closure on both the Ranger project area and surrounds. This closure model is now the subject of review and refinement internally and with stakeholders. This model, which is progressively refined, has been used as the basis for calculating the

financial provision required for eventual closure at the end of mine life. At the end of 2005 the net present value of the closure model for the Ranger project area and surrounds was estimated at A$186 million, fully provided for in the balance sheet. In mid-2011 the provision for rehabilitation and closure had grown to $550 million, with detailed studies continuing into 2012. In 2013 the estimate was $640 million. At the end of 2016, after substantial work had been commenced, the company had a rehabilitation provision of A$511 million plus provision for another A$100 million if required.

In 2013 ERA was carrying out a $23 million prefeasibility study on an integrated tailings, water and closure strategy, work on which was ready to commence. Some 10 Mt waste rock backfill had been placed into pit 3 by mid-2013. Mill tailings were sent there from the start of 2015. From December 2015 the company has been dredging the tailings dam and sending 4.4 Mt/yr to pit 3. This will be followed by the remainder of low-grade ore after 2020. Waste rock will be used as capping. Much of the cost of rehabilitation is a $220 million brine concentrator to clean up tailings water for discharge, using heat. It produces a brine (95 ML/yr at pH 1.8 and total dissolved solids of 400,000 ppm) which is injected into the waste rock underfill at the bottom of pit 3, and 1300 ML/yr of clean water. It was commissioned in September 2013. In pit 1, filled with tailings, after a pre-load rock layer to compress the tailings and dewater them via 7700 dewatering wicks, initial coverage with laterite was completed in 2016 ready for waste rock covering to be followed by final landform shaping and revegetation over 39 ha.

ERA, separately, is obliged to secure funds for certain costs of rehabilitation in case of any need for premature closure. An annually amended plan is submitted to government outlining this provision, which is reviewed by an independent auditor. Money for this purpose is partly in a trust fund administered by the Commonwealth government and partly covered by bank guarantee.

See also ERA website.

Olympic Dam

The Olympic Dam copper and uranium mine, with the town of Roxby Downs, is located 560 km north of Adelaide, near the opal mining centre of Andamooka. This is an arid part of Australia, receiving only an average of only 160 mm of rain per year, and that rather unreliably. The massive deposit is underground, some 350 metres below the surface, and besides its primary significance as a copper orebody, it is the largest known uranium orebody in the world.

History

The deposit was discovered in 1975 by Western Mining Corporation Ltd which was looking for copper in buried sedimentary rocks. After considering geophysical data a drill hole was sunk near a small stock water dam known as Olympic Dam. It struck copper, and later drilling confirmed a resource of more than 2000 million tonnes of ore containing both copper and uranium. From 1979 the deposit was evaluated as a Joint Venture with British Petroleum Ltd. In 1985 it was decided to proceed with the project, and production commenced in 1988.

WMC (Olympic Dam Corporation) Pty Ltd is the management company, a wholly-owned subsidiary of BHP Billiton Limited, which took over WMC Resources in mid-2005. Initially BP Minerals Ltd was a 49% partner in the enterprise, but WMC took over BP Minerals' share in 1993 for $315 million.

Over 1996-99 WMC undertook a A$ 1.25 billion program to more than double annual production to 200,000 tonnes copper and 3700 tonnes uranium concentrate (from 1500 tonnes). This expansion program was then accelerated, with the cost eventually rising to A$ 1.94 billion and the uranium capacity to 4600 tonnes U_3O_8 per year (which later declined to 4100 t/yr with decreasing grades).

OD expansion: WMC plans

Before the mid-2005 takeover by BHP Billiton, WMC Resources committed A$ 50 million over two years to assess the potential for doubling the size of Olympic Dam and in particular to take the resource categorisation of the southern orebody through to proven reserves and thus demonstrate the viability of a much expanded operation –

up to 15,000 t/yr U_3O_8 (with 500,000 t/yr copper). The capital cost involved was estimated as at least A$5 billion. Some $4 billion had already been invested in the mine by WMC, including $680 million over 2001-04, and in 2004 the mine generated A$ 1100 million in export income. The WMC study included drilling on the southern deposit (later: Southern Mining Area) and assessing mining options including possibly a massive open pit (3 km wide, 1 km deep) to access the orebody. Up to June 2007 over 2000 km of drilling has been involved in defining the orebody.

OD expansion: BHP open pit and staged expansion plans 2005 to 2012

BHP Billiton then made a fresh appraisal of the possibilities on the basis that the previous assessment of market potential was too conservative. In October 2008, five stages of this expansion were defined, without a specific timeline. A pre-feasibility study to decide among the development options, and a 4600-page draft environmental impact study, were completed in 2009. The EIS (summary p20) stated: "Drilling of the ore body undertaken by BHP Billiton since 2005 has more than doubled the resource estimate from 3.98 billion tonnes of total mineral resource to 8.34 billion tonnes. At the same time, the expected demand and prices for the minerals means underground mining is no longer the preferred option for such a large ore body. Consequently, open pit mining has become the most feasible option for mining more of the resource. Underground mining can extract only about 25% of the ore containing recoverable quantities of copper, uranium, gold and silver, while an open pit would extract up to 98% as large zones of lower-grade mineralisation that were uneconomical for underground mining can be profitably bulk mined." In May 2009 the time span of progressive development was estimated as about 11 years from 2010.

The open pit would be developed over five years, removing overburden to expose the first part of the main orebody. Mining from it would then commence in mid-2016, and the pit would continue to be developed. The pit would eventually be 4.1 x 3.5 km, and 1000 m deep, and the waste rock storage about 67 km^2 to a height of 150 m. Tailings storage would extend the existing facility to about 40 km^2 and 65 m high to take 58 Mt/yr.

The main metallurgical plant (concentrator) would be developed in three successive 20 Mt/yr stages from 2012. A new hydrometallurgical plant to treat the tailings from this would be developed in conjunction. The existing electro-refinery and smelter would be upgraded to continue processing ore from either the existing (and continuing) underground operation or the open pit. However, two-thirds of the copper concentrate including some of the uranium would be exported to a dedicated smelter in China or Japan (see Appendix – OD expansion: BHP reduced smelting plans 2007 to 2014).

Required infrastructure would include: a 200 ML/day desalination plant (reverse osmosis) on Spencer Gulf, supplying the operation; much increased power provision by 650 MWe; a 105 km rail spur; a new airport; and accommodation expansion at and near Roxby Downs. Some of the power increment – about 250 MWe – could eventually be met by a cogeneration plant harnessing waste heat from burning sulfur at the acid plant. Most of it would need to come either from the grid or a 600 MWe combined cycle gas turbine plant at Olympic Dam.

A draft environmental impact study was released on 1 May 2009, and a Supplementary EIS was submitted to the government in December 2010. BHP Billiton moved the project to feasibility study stage in March 2011, and government approval was announced in October 2011.

However, in August 2012 BHP Billiton put the $28 billion project on hold while it investigated less-costly alternatives. In November 2012 the state government granted a four-year extension, conditional on the company spending $650 million on pre-project research on heap leaching and on community work.

OD expansion: BHP underground expansion and heap leach plans from 2014

In July 2014 BHP Billiton applied for government approval to build and operate a demonstration-scale heap leaching plant at Olympic Dam. Heap leaching has not previously been used for uranium ore in Australia (that at Rum Jungle over 1965-71 was for copper), though it is increasingly favoured for low-grade hard-rock uranium ores overseas. BHP-B uses it on a large scale at its Spence copper mine in Chile. Laboratory and pilot scale trials of the technique using run of mine ore from the existing operations have shown promising results to date. The company expected to start construction of the demonstration plant in the second half of 2015, with a three-year trial period starting in late 2016.

Some 36,000 tonnes of ore – about one day's current mine production – is being used in the trial. The ore will be crushed, placed on an impermeable leach pad and treated with sulfuric acid for 300 days. This is expected to recover most of the uranium, and with the help of bacteria, something like half of the copper. The uranium would then be removed from the pregnant liquor by solvent extraction, after which the copper would be removed electrolytically. This essentially reverses the present sequence where most of the uranium is recovered by acid leaching the mill tailings after copper sulfide flotation. Following the heap leaching, the depleted ore remaining will be further crushed, ground and put through a dedicated flotation plant onsite to recover the rest of the copper as sulfide, which would then be smelted as at present for all production. In September 2017 the company announced the first copper cathode from the trial.

In a general announcement about productivity in November 2014, BHP Billiton flagged a 27% increase in copper production at Olympic Dam from 2018 by streamlining haulage and treatment, and a doubling from that level subsequently by "a low-risk underground expansion with significantly lower capital intensity than the previous open cut design. This has the potential to deliver over 450,000 tonnes of copper production a year at first quartile C1 costs by the middle of next decade." The uranium implications are not mentioned, but assuming the same head grades, it would mean 5000 t U_3O_8 from 2018 and some 10,000 t/yr in the mid-2020s. In September 2017 the company announced the first production from the Southern Mining Area, and that it had spent A$250 million in the 2017 financial year on expanding operations into that area.

In July 2016 the company confirmed that it would now focus on underground development only, and its increased copper production would involve a corresponding increase in uranium production.

Aerial view Olympic Dam plant.

Production and sales

Olympic Dam is an underground mine. Some 12 million tonnes of ore is mined each year by open stoping.

In 2001 the plant suffered a fire in the solvent extraction plant and production remained low for two years. In October 2009, the haulage system in the mine's Clark Shaft was damaged. While hoisting continued at the secondary Whenan Shaft, capacity was reduced to about 25% until full production resumed in June 2010.

In 2013 production was 4008.7 tonnes U_3O_8 (3399 t UOC, 3386 tU) – about 6% of world mine total. Uranium recovery has been 65-70%, due to about half of the uranium being in the form of refractory brannerite, and this is a focus for improvement, with 72.8% recovery being achieved in 2008. Production in 2014 was 3952 tonnes U_3O_8, and in 2015 it was 3749 tonnes.

Sulfur dioxide from the copper minerals is made into acid and used in uranium processing.

About 20% of Olympic Dam's revenue is from uranium, 75% from copper and 5% gold and silver.

Sales of uranium concentrate are made under long-term contracts to electric utilities in Canada, USA, Japan, South Korea, China, Finland, Sweden, Belgium, France and the United Kingdom.

Process

Following primary crushing underground, the ore is ground and treated in a copper sulphide flotation plant. About 80% of the uranium minerals remain in the tailings from the flotation cells, from which they are recovered by acid leaching. The copper concentrate is also processed through an acid leach to recover much of the other 20% of the uranium. The pregnant liquor is then separated from the barren tailings and in the solvent extraction plant the uranium is removed using kerosene with an amine as a solvent. The solvent is then stripped, using an ammonium sulphate solution and injected gaseous ammonia. Yellow ammonium diuranate is then precipitated from the loaded strip solution by raising the pH, and removed by centrifuge. In a furnace the diuranate is converted to uranium oxide product, U_3O_8.

Some uranium remains in the leached copper concentrate which goes to be smelted, and it is recovered in the smelting or electro refining stages.

Ore

The deposit occurs in the basement rocks of the Stuart Shelf geological province in the north of South Australia. Mineralisation consists of medium-grained chalcopyrite ($CuFeS_2$), bornite (Cu_5FeS_4) and chalcocite (Cu_2S), fine-grained disseminated pitchblende and brannerite (U minerals), gold, silver and rare earth minerals that occur in a magnetic hydrothermal breccia complex beneath 350m of overburden. The ore occurs in distinct zones that determine the mine access and layout. (mining-technology.com & infomine)

Reserves & resources

Olympic Dam has enormous reserves of ore, with 347,000 tonnes of contained uranium oxide. The overall resource contains some 2.45 million tonnes of uranium oxide in a hematite breccia complex. While the grade of the uranium ore is lower than many mines or potential mines which have the benefit of open cut operation, the fact that copper is a co-product with uranium from that same ore (at 1.8% Cu in the reserves) means that such grades are viable.

Olympic Dam Uranium Ore Reserves and Resources at 30/6/16

	Ore or resource (million tonnes)	Grade U_3O_8 (%)	Contained U_3O_8 (tonnes) calculated
Proved ore reserves: sulphide	151	0.061	92,110
Proved ore reserves: low-grade	7.1	0.036	2,556
Probable ore reserves: sulphde	354	0.057	201,780
Probable ore reserves: low-grade	28	0.035	9,800
Total reserves	505 + 35	0.058 & 0.035	292,900 + 12,250
Measured resources	1390	0.029	403,100
Indicated resources	4800	0.024	1,152,000
Inferred resources	4220	0.024	1,012,000
Total resources	10,400	0.025	**2,568,000**

NB. Resources inlcude reserves. Quoted metallurgical recovery from reserves is 72%.

The figures announcing a 27% increase in uranium resources, to 2.24 million tonnes of uranium oxide (1.9 MtU) in September 2007 were based on 2095 km of drilling over the previous two years and confirmed the deposit as the world's largest for uranium. It covers an area of over 6 km by 3.5 km, is up to 2 km deep and remains open laterally and at depth as the drilling program continues, further results being reflected in the above Table.

Occupational health & safety

The mine is well ventilated with powerful fans so that radiation exposure from radon daughters is very low. Exposure from gamma radiation is also minimal, due to the low grade of uranium mineralisation. The average annual radiation exposure level (over the 1.5 mSv/yr background) for all designated underground workers in 1999-2000 was 1.7 millisieverts (ranging up to 9.9 mSv). These levels compare very favourably with the annual limit of 20 mSv/yr averaged over five years.

The site has implemented a Safety Management System which is compliant to Level 3 Exempt Status under the

state occupational safety organisation, and this has been officially recognised.

Infrastructure

Expansion of the mine will bring major infrastructure challenges. The present 12 GL/yr water consumption (met from the Great Artesian Basin) will grow, possibly to 70 GL/yr, requiring a coastal desalination plant with pipeline to Olympic Dam. The operation now uses 10% of the state's base-load power (870 GWh/yr) and the expansion will add demand for another 650 MWe and 4400 GWh/yr, the source of which remains to be determined. The CO_2 output from power generation attributable to the operation is likely to grow from 0.9 to some 4.7 Mt/yr.

Environmental management

The mine lease of 18,000 hectares is managed by BHP Billiton Olympic Dam. The mine, smelter and infrastructure occupy about 7.5% of the lease area. Environmental management activities account for approximately one third of expenditure from the overall environmental budget, which is in excess of A$ 2 million. In February 2005, Olympic Dam was successful in obtaining ISO14001 certification for the site Environmental Management System.

The mine lease and the adjacent 11,000 hectare municipal lease have been destocked (of sheep and cattle) since 1986. Following the release of rabbit haemorrhagic disease (RHD), rabbit numbers in the region dropped significantly, and are currently at approximately 40 per square kilometre, compared with plague numbers of up to 600 /km^2 in the late 1980s. Red Kangaroo numbers on the mine lease are about 20 per square kilometre, which is slightly higher than surrounding areas because of the access to water. In order to discourage wildlife from entering the tailings storage facility, alternative waterholes have been provided and deterrents installed on the dams and ponds. The evaporation ponds have been fenced with fine mesh to exclude small mammals and reptiles. Foxes and cats are controlled on the lease by shooting and trapping.

BHP Billiton Olympic Dam manages four pastoral stations in the area surrounding the mine and municipal leases with a total area of 1,136,000 hectares. These properties are conservatively stocked to maximise protection of sites of environmental or cultural significance.

The Arid Recovery project, which covers an area of 8,600 hectares, is situated largely on the mine lease and BHP Billiton-operated pastoral stations, with the remaining area (6 hectares) donated by local pastoralists. Arid Recovery is an ecosystem restoration initiative working to restore Australia's arid lands. The program is a partnership between BHP Billiton, the South Australian Department for Environment and Heritage, the University of Adelaide and the community group Friends of Arid Recovery. The reserve is surrounded by a unique cat, rabbit and fox-proof fence. Five locally extinct species have been reintroduced into the reserve.

Before clearing is undertaken for any development work or exploration on the mine and municipal leases, an Environmental/Indigenous Heritage Clearance Permit is required. During this process, all significant slow-growing trees and shrubs and areas of cultural significance are identified. Efforts are made to minimise disturbance caused by operational activity on the leases, and rehabilitation is undertaken afterwards where practical. Considerable attention has been given to rehabilitation of the hundreds of drill pads, some dating from initial exploration, so that many are now scarcely visible even on aerial photos.

Rock waste and the coarse fraction of tailings are used as mine backfill. Fine tailings material, still containing potentially valuable minerals (rare earths etc.) is emplaced in tailings dams on the lease covering about 400 hectares.

During 1994 seepage of contaminated water from the tailings dams was identified. This was of concern to the company, the regulators and the public because of the perceived threat to the quality of groundwater immediately below the tailings dams. Studies undertaken demonstrated that the pollutants in the seepage were quickly adsorbed on to clays and limestone in the soil and rock under the tailings dams, and, due to the low permeability and transmissivity of the rock, that there was no potential harm to the groundwater resource. The level of the groundwater under the tailings dams is monitored and modelled on a quarterly basis.

BHP Billiton Olympic Dam submits an Environmental Management and Monitoring report annually to the Department of Primary Industries and Resources South Australia (PIRSA) and the Environment Protection Authority (EPA). This comprehensive report covers all areas of potential environmental impact, including air emissions, site groundwater management, water supply and management of the Great Artesian Basin, flora and fauna monitoring and annual radiation dose to members of the public. Reporting on progress with action items identified in the Environmental Management Program is provided, as well as involvement with community activities.

The annual Sustainability Report is on the web
http://bhpbilliton.com/bb/sustainableDevelopment/reports.jsp

Olympic Dam has a Rehabilitation and Closure Plan covering cost estimate basis, summary of closure requirements (for the metallurgical facilities, pilot plant, mine, tailings dams, wellfields, exploration areas, town facilities, power line corridor and miscellaneous facilities), community consultation requirements, closure strategy (including post operational land use objective and completion criteria) and closure plan review requirements. The plan provides a breakdown for each area to be decommissioned, including engineering works required (ie demolition and cleaning), environmental works (removal of contaminated material and rehabilitation), specific closure obligations for each area of plant, final land use objectives, closure assumptions, closure material sources, waste disposal sites, cost saving opportunities and liabilities/risks/hazards.

Demolition costs are budgeted based on quotations from a specialist demolition contractor and rehabilitation costs are estimated based on a quotation from a mining contractor with extensive rehabilitation experience. Progressive closure costs have been estimated for each year until actual closure of the site. The financial provision – A$ 244 million at mid-2006 – is calculated in line with BHP Billiton Accounting Standards.

Beverley and Four Mile

Over 2013-14 the scene has changed here, with Beverley and then Beverley North suspending production, and from January 2014 to late 2016 all production came from Four Mile.

The **Beverley** uranium deposit is 520 kilometres north of Adelaide, on the plains northwest of Lake Frome and 25 kilometres northeast of the Arkaroola Resort in the northern Flinders Ranges. Beverley North is a contiguous lease. Beverley itself is a relatively young sandstone deposit in palaeochannels with uranium mineralisation leached from the Mount Painter region, and was the basis of Australia's first commercial in situ leach (ISL) operation. In 2008 a major mine lease extension was obtained to the north, and that the lease is now contiguous with the Four Mile lease to the north and west of it. However the mineralisation at Beverley North and Four Mile is in alluvial fan deposits which extend from the ranges out under the Beverley palaeochannels.

History and Background

Beverley was discovered in 1969 by the OTP Group (Oilmin NL, Transoil NL, & Petromin NL). A draft EIS was produced in 1982 but plans to mine it by in situ leaching (ISL) were abandoned in 1983 when a newly-elected South Australian Government made it clear that mining leases would not be approved. The deposit was sold to Heathgate Resources Pty Ltd, an affiliate of General Atomics of USA, in 1990.

The main Beverley deposit consists of three mineralised zones (north, central and south) in a buried palaeochannel (the Beverley aquifer) in tertiary sediments of the Frome basin. Groundwater salinity ranges from 3000 mg/L total dissolved solids in the north to 12,000 mg/L TDS in the south. The aquifer is isolated from other groundwater, notably the Great Artesian Basin about 150 metres below it and small aquifers in the Willawortina Formation above, which are used for stock watering.

A field leach trial in 1998 was successful, with performance three times better than similar deposits in USA, and it established the commercial viability of the project. A new draft EIS was released for public comment in July 1998 and the Supplement in October, with environmental approval being given in March 1999. Other approvals were in April 1999. Mine construction started in 1999, including processing plant, camp, airstrip, 4.0 MWe gas-fired power station and two wellfields.

As the main orebodies became depleted, in 2009 the Beverley North project was initiated and in 2010 a field leach trial at Pepegoona was successful. This became a satellite operation, with loaded resin being trucked to the treatment plant. In 2011 mining commenced at Pannikin, with a second satellite plant. These northern orebodies are closer to the Flinders Ranges and more complex geologically than the palaeochannel deposits. The satellite plants are on the lease boundary with the Four Mile JV with Alliance Resources. In December 2013 production from the Beverley wellfields was suspended, leaving only Beverley North operational for Heathgate, but this too was suspended from January 2014 to late 2016.

Four Mile comprises three alluvial fan deposits 5-10 km northwest of the Beverley mine and was explored by Quasar Resources Pty Ltd (a subsidiary of Heathgate Resources). The extended Beverley mine lease is contiguous. Alliance Resources Ltd through subsidiary Alliance Craton Exploration (ACE) was a 25% free carried joint venture partner. JORC-compliant resources are 32,000 t U_3O_8 at 0.33%. Both the quantified deposits remain open, with potential for further resource upgrade. They are about 3 km apart. A third deposit is about one kilometre northeast, with 22,700 t U_3O_8 inferred resources (mid-2015) and an exploration target of 32,000 to 36,500 t U_3O_8 grading 0.27-0.30% U_3O_8 over 2.2 km strike length. Four Mile East is about 120 m deep and with good flow, Four Mile West is deeper and tighter.

Quasar applied for a mining lease in May 2008. An environmental assessment was published in January 2009. The mining lease was subject to registration of a Native Title Mining Agreement (NTMA), which was delayed, but a 10-year mining lease was granted to the partners in April 2012, and environmental approval in August 2013. Quasar commenced mining the East orebody in April 2014, using its nearby Pannikin satellite plant 2.5 km away, and then trucking the loaded resin to Heathgate's main plant 10 km away for product recovery.

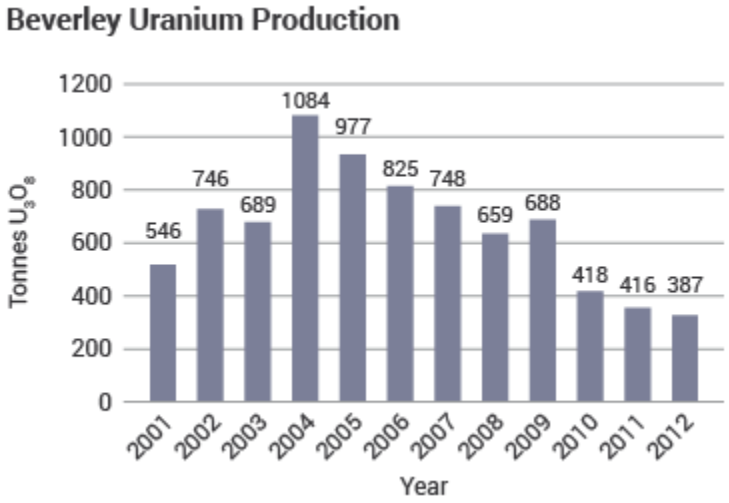
Quasar has been drilling a further area on Alliance's lease, at Four Mile Northeast, centred some 1200 metres northeast of the East orebody and close to Heathgate's Pannikin satellite plant. This is highly prospective, but no JORC-compliant figures are yet available.

Quasar has used its 75% interest to dictate development policy and timing for Four Mile. Alliance has dissented and taken legal action, but in June 2014 Alliance settled with Quasar, paying out $4.557 million for costs. Alliance contends that a separate treatment plant for Four Mile would be better economically than paying Heathgate to process the loaded resin. In May 2012 Alliance had entered an agreement with Itochu Corporation to take a 14.9% share in the company and then possibly 25.1% more. If both options were exercised the company would have been able to fund a stand-alone ISL operation at Four Mile, independently of Heathgate and the toll treatment at Beverley. Itochu taking up the equity was contingent upon restoration of Alliance's full ownership of the deposit, which did not happen. In July 2014 Alliance solicited bids to buy its share of Four Mile.

For Beverley, Heathgate negotiated a royalty equivalent to 2% of gross sales with four Aboriginal Native Title Claimant groups, and the first payments totalling more than $100,000 were made to trust accounts in mid-2000. The agreements also provide for training, employment, community payments and administration payments.

Production and Sales:

Production from Beverley, licensed to reach 1180 t/yr U_3O_8 equivalent, commenced from the north mineralised zone in November 2000 though no product was drummed until 2001. Exports commenced in 2001. Production for 2004 reached 1084 tonnes U_3O_8 but then steadily dropped to around 400 tonnes from 2010 and in 2013, the last full year of operation involving the main orebodies, 98% of production was from Pepegoona and Pannikin on the Beverley North lease until production ceased there in January 2014. These Beverley North orebodies are adjacent to Four Mile. Sales contracts are with power utilities in the USA. The last production from Beverely was in 2014, until 100 t was produced in the second half of 2016.



From Four Mile, Quasar expected to spend A$ 77 million, excluding any development of the West orebody. Cash operating costs (A$28) plus development costs to end of 2014 work out to about A$ 40/lb U_3O_8, with sale price expected to be A$ 49/lb. The production rate in mid-2014 was 1200 t/yr U_3O_8, which is about the capacity of the Beverley mill. In 2014, 755 t U_3O_8 was produced, rising to 935 tonnes in 2015. The first two shipments of product (total 213 t U_3O_8) were in September and October 2014, to Cameco Blind River, and the balance was stockpiled.

For the 13 months from December 2014 through 2015 Quasar anticipated production of 1200 t U_3O_8 from Four Mile, which would all be stockpiled. Expenditure of $108 million was planned, including capital. Cash operating costs are budgeted at $32/lb plus development costs of $9, total $41/lb U_3O_8.

Due to Quasar's refusal to sell product, thereby depriving Alliance of funds, ACE refused to contribute to the 2015 program and budget. This meant that ACE's share of the project would reduce from 25% to about 15% by the end of 2015. In November 2014 ACE terminated Quasar's appointment as sales and marketing agent of ACE's share of Four Mile product and instituted proceedings in the Supreme Court of South Australia seeking a declaration that the termination is valid and to order that ACE's share of product be delivered up to ACE. In May 2015 Alliance received a permit to possess uranium concentrate. It applied for permits to transport and export.

In February 2015 Alliance received an offer from Quasar to purchase all of ACE's interest in the Four Mile Project, including ACE's share of uranium oxide concentrates already mined (worth over $20 million), for AUD $57.6 million. This was raised to $74 million in July 2015, which Alliance accepted.

Resources

At Beverley, several ore lenses in unconsolidated sands lie at a depth of 100-130 metres, over some 4 km of palaeochannel. The three initially mined contained at least 21,000 tonnes of uranium oxide at 0.18% grade, mostly recoverable by in situ leaching. In November 2006 the company applied to extend the mine lease to take in contiguous ground at Beverley North including Pepegoona (with 4000 t U_3O_8) and Pannikin. The cumulative total recovered from Beverley and Beverley North to shut-down in January 2014 was 8614 tonnes U_3O_8.

At Four Mile, the West deposit has 14,000 t indicated resources and 4700 t inferred resources, at 0.34%. Alliance in June 2009 confirmed 13,000 tonnes U_3O_8 at 0.31% inferred resources for the East deposit, making a total of 32,000 t U_3O_8 at 0.33% (27,100 tU at 0.28%U). A cut-off of 0.5 metres at 0.10 m% grade thickness (GT) was used for both resource estimates, assuming ISL mining.* Both deposits remain open, with potential for further resource upgrade. They are about 3 km apart. There are three mineralised layers between 190 and 210 metres deep, ranging from 1.1 to 7.3 metres thick and with grades up to 1.74% U_3O_8.

* ISL resources are reported in terms of grade thickness (GT) – average grade U_3O_8 multiplied by thickness of leachable sand holding the uranium.

Some additional mineralization has been identified in the western area of Four Mile West, which has the potential to add up to 30% to that resource if this mineralization is proved recoverable by ISL, or mineable by other means.

For Four Mile Northeast, some 1200 metres northeast of the East orebody and close to Heathgate's Pannikin satellite plant, Alliance has an exploration target of 32,000 to 36,500 t U_3O_8 grading 0.27-0.30% U_3O_8 over 2.2 km strike length, with a JORC-compliant inferred resource figure pending (24 Feb & 20 March 2015). The exploration target figure is for an area stretching from Four Mile East past Pannikin almost to Pepegoona, though the mineralisation is interpreted to lie within an apparent regional roll-front type redox interface that embraces the Four Mile West, Four Mile East, Pannikan and Pepegoona deposits over a total strike length of 7.5 km.

Mineral resources at Four Mile, 30/6/15

	Grade % U3O8	tonnes U3O8	JORC class
Four Mile West	0.34	14,520	indicated
	0.31	4,080	inferred
Four Mile East	0.31	13,160	inferred
Four Mile Northeast	0.30	22,686	inferred

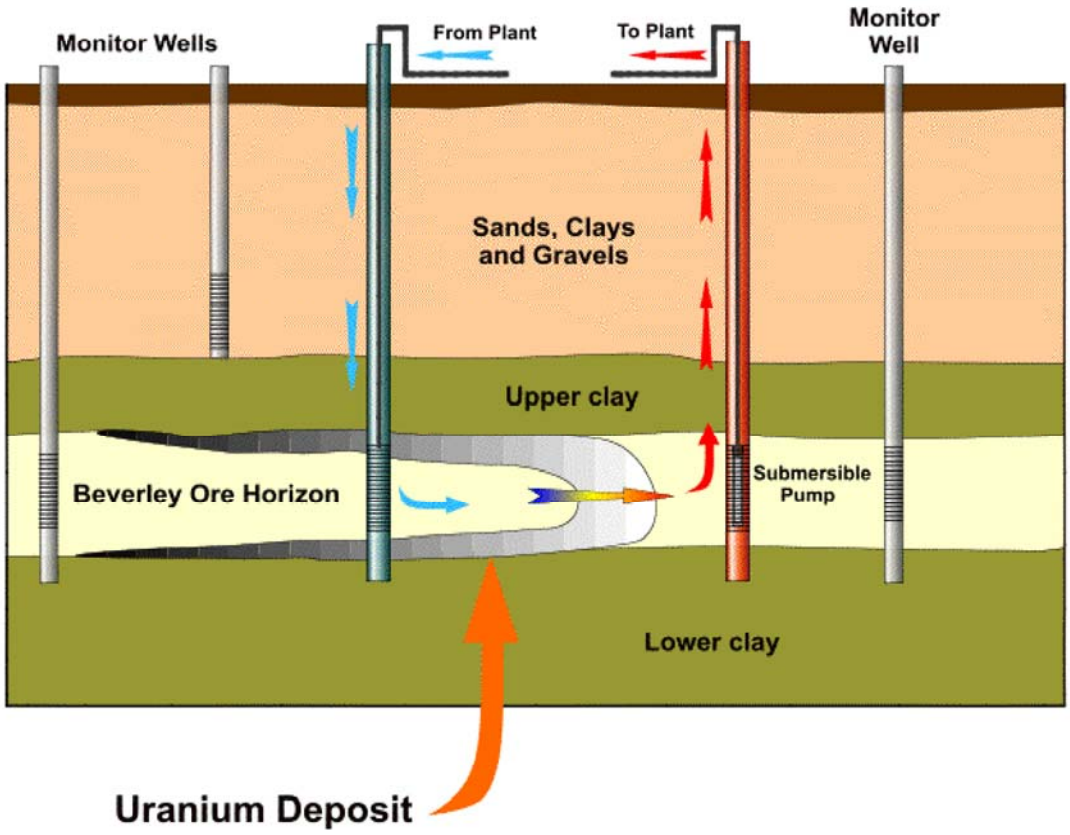
Grade thickness cut-off is 0.10%. Source: Alliance

Process

The mines consist of wellfields which are progressively established over the orebody as uranium is depleted from sections of the orebody immediately underneath. Wellfield design is on a grid with alternating extraction and injection wells, each of identical design and typical of normal water bores. The spacing between injection wells is about 30 metres with each pattern of four having a central extraction well. A series of monitor wells are situated around each mineralised zone to detect any movement of mining fluids outside the mining area.

Beverley wellfield

Submersible electric pumps initially extract native groundwater from the host aquifer prior to the addition of uranium complexing reagents (acid) and an oxidant (hydrogen peroxide or oxygen) before injection into the wellfield. The wells are cased to ensure that liquors only flow to and from the ore zone and do not affect any overlying aquifers. They are pressure tested before use. The leach liquors pass through the ore to oxidise and dissolve the uranium minerals in situ. The pregnant solution from the production wells is pumped to the treatment plant or satellite plant where the uranium is recovered in a resin ion exchange (IX) system. If at a satellite plant, the loaded resin is trucked to the central treatment plant.



The uranium is then stripped from the ion exchange resin, and precipitated with hydrogen peroxide. The uranium slurry is dewatered and dried to give hydrated uranium peroxide ($UO_4.2H_2O$) product. From 2010 it was expected that the plant would also treat loaded resin trucked in from the Four Mile project adjacent to the Beverley North satellite operations. In fact, from 2011 it treated resin trucked from Pepegoona and Pannikin, further north than this, and 70m from the Four Mile lease boundary. In April 2014 it commenced recovery of uranium from the Four Mile JV, with the resin loaded at the Pannikin satellite plant.

Before the remaining process solution is reinjected, it is oxygenated and if necessary recharged with sulfuric acid to maintain a pH of about 2.0 to 3.0. Most of the solution is returned to the injection wells, but a very small flow (about 0.5%) is bled off to maintain a pressure gradient in the wellfield and this, with some solutions from surface processing, is treated as waste. It contains various dissolved minerals such as radium, arsenic and iron from the orebody and is reinjected into approved disposal wells in a depleted portion of the orebody. This bleed of process solution ensures that there is a steady flow into the wellfield from the surrounding aquifer, and serves to restrict the flow of mining solutions away from the mining area.

Beverley ISL processing plant

Occupational Health and Safety

The usual radiation protection measures are applied, despite the fact that most of the orebody¹s radioactivity remains well underground and there is hence minimal increase in radon release and no ore dust. Designated employees wear personal dosimeters to measure exposure to gamma radiation and radon daughter concentration is measured regularly in the plant area. Routine monitoring of air, dust and surface contamination is also undertaken.

Environmental Management:

An Environmental Management and Monitoring Plan (EMMP) has been developed with the regulating authorities, who determined the requirements of it, including those for radiation protection. The Plan provides for ongoing management of every aspect of the operation. Monitoring to detect possible horizontal excursions from the mining zone or any vertical leakage into other aquifers is a fundamental facet of mine operations.

In contrast to the main ISL operations in USA extracting uranium from aquifers with potable water, the groundwater quality at Beverley is very low, being fairly saline and orders of magnitude too high in radionuclides for any permitted use to start with. Fluids from mined areas are progressively moved to new mining areas, thus reducing the overall effect on the aquifer. After completion of mining, when oxygen input and leaching are discontinued, the groundwater reverts to about pH 4.5, and then over time to its original condition at about pH 7.

Heathgate bought the 2350 sq km Wooltana pastoral lease, from which the 13.5 sq km project area is fenced off and destocked. This area, mainly Mitchell grass plain, will be allowed to rehabilitate naturally to guide later revegetation of mined areas.

Upon decommissioning a wellfield, wells are sealed and capped, pipes are removed and the surface revegetated progressively. At the end of the mine's life, process facilities will be removed and after discussion with the stakeholders the land can revert to its previous uses. Heathgate has provided financial guarantees to the state government in respect to ongoing mine site rehabilitation up to the final completion of mining.

Honeymoon

The Honeymoon mine in South Australia was commissioned in 2011 with 340 t/yr U_3O_8 capacity. It was then closed at the end of 2013 due to technical issues coupled with low uranium prices, and in 2015 Boss Resources Ltd took it over.

In April 2016 Boss reported indicated resources of 3840 tonnes U_3O_8 for Honeymoon itself and Brooks Dam, and inferred resources of 3690 tonnes for Brooks Dam Extension and East Kalkaroo, as well as 7193 tonnes for Gould's Dam, further away. In mid-2016 it announced a 2000 tU inferred resource for the Jason deposit, at the north end of the Yarramba paleochannel, after reviewing historic drill data. This brought global figures for Honeymoon plus Gould's Dam to 26,270 tonnes U_3O_8.

The Honeymoon - East Kalkaroo deposit occurs in porous sand of the Yarramba palaeochannel at a depth of 90-120 metres and extending over about 150 hectares. Plans were developed in the late 1970s to extract the uranium oxide by in situ leaching (ISL), and some $12 million was spent in preparation. Draft and Final Environmental Impact Statements were produced, and both South Australian and Commonwealth environmental approval was subsequently obtained in 1981 for production to 450 t/yr U_3O_8. Field tests of the ISL process were carried out and a $3.5 million, 110 t/yr pilot plant was built, but the project was abandoned in 1983. The aquifer has 8-10 g/L of chlorides, higher than other ISL projects, and at the time therefore requiring solvent extraction rather than ion exchange (better resins are now available). Mineralisation includes a significant proportion as phosphates, as well as uraninite and coffinite.

The deposit itself was discovered in 1972, about 75 kilometres northwest of Broken Hill, 30 kilometres inside South Australia. MIM Holdings Ltd bought out CSR Ltd's 34.3% share in 1988. In 1997 Sedimentary Holdings NL reached agreement with MIM to acquire the Honeymoon leases next to its own East Kalkaroo deposit on the Yarramba palaeochannel. The 1997 agreement also included acquisition of the Gould Dam-Billaroo West leases 75 km

northwest of Honeymoon. The 1997 agreement initially brought together known uranium resources of about 4200 tonnes U3O8 averaging 0.11% and amenable to in-situ leaching. The purchase was funded by Southern Cross Resources Inc. of Toronto. Sedimentary Holdings progressively reduced its share in Southern Cross and sold the last 7% in September 2004.

Aerial view of plant and infrastructure (wellfield is beyond at top left

Trial wellfield (extraction well is left of centre)

Well header building

Inside well header building

Pilot plant

Field leach trials using the refurbished process plant resumed in 1998 and led to a proposal to produce about 1000 t/yr U_3O_8 equivalent (as uranium peroxide) at low cost. A June 2000 draft EIS covered the Honeymoon - East Kalkaroo deposits and this was approved in November 2001.

Further drilling and logging with a prompt fission neutron (PFN) tool in 2004 confirmed high-grade resources which were reported in terms of grade thickness (GT) – average grade U_3O_8 multiplied by thickness of leachable sand holding the uranium. In the Honeymoon deposit itself 3300 t U_3O_8 at an average GT of 0.84 m% was confirmed, with 900 t U_3O_8 at an average GT of 0.38 m% in East Kalkaroo adjacent. The program failed to extend these resources, and further drilling and logging of nearby parts of the Yarramba palaeochannel immediately NW of Honeymoon in 2004 failed to confirm further resources.

In 2004 the company revised development plans down to a 400 tpa plant at Honeymoon, but development was deferred pending the outcome of further exploration at Gould's Dam. In December 2005 Southern Cross Resources was taken over by Aflease to form sxr Uranium One Inc. (The 'sxr' was later dropped.) Following a new feasibility study, in August 2006 Uranium One announced that development of Honeymoon would proceed as a 400 t/yr ISL mine. It quoted indicated resources then of 2900 tonnes U_3O_8 at 0.24% (av grade thickness 0.42 m%) excluding some thin low-grade material included in earlier estimates. The adjacent East Kalkaroo deposit had 900 tonnes at 0.074% grade. In January 2007 a ten-year export permit was granted.

In October 2008 Uranium One announced a joint venture with Mitsui (49%) to complete development of the project, with Mitsui paying $104 million towards the eventual $138 million cost. Similar joint ventures with Mitsui would apply to Gould Dam and Billeroo.

In December 2008 Uranium One announced an engineering, procurement, and construction management contract with Ausenco Ltd to build the mine. Total capital cost envisaged was A$ 118 million, including pulsed column solvent extraction (SX) circuit. A mine life of six years (including ramp-up) was expected. In 2011 capital expenditure of about $20 million comprised $10 million for wellfield development and $10 million for other construction activities and fixed asset purchases. Four wellfields were established. Mitsui's A$ 104 million largely funded the commissioning. Capital expenditure took the total investment in the mine to $170 million.

In May 2012 Mitsui announced that it was withdrawing from the project. The parties negotiated the terms of this, and Uranium One "recognised a gain of $17.2 million as a result of the transaction." A February 2012 report quoted reserves of 2890 tonnes U_3O_8 at 0.08% and indicated resources of 5400 tonnes U_3O_8 at 0.129%.

From 2009, 51.4% of Uranium One Inc was owned by Russia's ARMZ, but in 2012 ARMZ moved to buy out all the other shareholders. It then had full ownership of the Canadian-based company. In November 2013 Rosatom set up Uranium One Holding NV to own and manage all its international uranium mining assets, including Uranium One Australia under Uranium One Inc, leaving ARMZ responsible for uranium mining in Russia.

In November 2013 Uranium One said it had "impaired the Honeymoon project due to continuing difficulties in the production process and issues in attaining design capacity, combined with high mine operation costs. The carrying value of Honeymoon was therefore written down by $67.8 million." A week later it was announced that the mine would be closed pending improved uranium markets and put on a care and maintenance basis.

In 2015 Boss Resources Ltd based in Perth bought Uranium One Australia, which owned the mine and asociated deposits, for A$ 11.5 million in staged payments plus up to $3 million from operating cash flow. Boss formed a joint venture with Wattle Mining Pty Ltd (Boss 80% and Wattle 20%) to take over Uranium One Australia. Boss has an option to acquire Wattle's 20% after completion of a bankable feasibility study.

Honeymoon and Gould's Dam resources: January 2015, April 2016 respectively

	Resources	ppm U_3O_8	Tonnes U_3O_8
Gould's Dam	indicated	650	2900
	inferred	480	8500
Honeymoon & contiguous	measured & indicated	1720 & 1270	4920
	inferred	640	7620
West and East tenements	total	640	23,800

Production: First production was in September 2011. Production in 2012 was expected to be 275 tonnes U_3O_8, at $47/lb – much more than the company's average cost of production in Kazakhstan, but commissioning was drawn out and resulted in only 155t production. In 2013 production was 112 tonnes U_3O_8 until it ceased by the end of the year. Total production over about two years was 312 tonnes U_3O_8. The uranium content of liquor was only two-thirds of the design level, which was the major factor among several which limited production.

Boss Resources said Honeymoon has "near-term production" potential on the basis of A$ 170 million plant and infrastructure in place. A preliminary feasibility study completed in May 2017 was positive for 400 t/yr U_3O_8 after 12 months start-up of present SX plant costing US$ 10 million, increasing to 900 t/yr with ion exchange (IX) plant for US$ 58 million. Potential expansion to 1450 t/yr was envisaged. A field leach trial commenced in June. Boss expects to complete a definitive feasibility study in 2017 and then recommence production in mid-2019, with with estimated All-in Sustaining Cost (AISC) below US$25/lb and direct operating cost under $16. In October 2017 it announced that the ion exchange (IX) pilot plant (replacing the solvent extraction circuit) was working well. This is located away from the main plant.

In November 2013 Uranium One said it had "impaired the Honeymoon project due to continuing difficulties in the production process and issues in attaining design capacity, combined with high mine operation costs. The carrying value of Honeymoon was therefore written down by $67.8 million." A week later it was announced that the mine would be closed pending improved uranium markets and put on a care and maintenance basis. Production ceased by the end of 2013.

Boss Resources says Honeymoon has "near-term production" potential on the basis of A$ 170 million plant and infrastructure in place. It expects to complete a definitive feasibility study in 2017 and then recommence production in mid-2019, with targeted cash cost below US$25/lb.

Appendix

OD expansion: BHP reduced smelting plans 2007 to 2014

In mid-2007 BHP Billiton proposed an alternative treatment strategy, which became part of the base case. This would involve exporting some product as copper concentrate rather than only refined copper, and hence exporting some uranium still contained in the copper concentrate. Because the Olympic Dam ore contains copper, uranium, silver and gold in close association, the common procedure of simply selling a copper concentrate with precious metals has not been viable, since some of the uranium would be in it, creating both processing and safeguards

complications for the smelter operator. Most of the uranium is removed at the flotation stage after the copper sulfide is separated from the remainder of the ore, which is then tailings, and the main uranium recovery is from acid leaching of these tailings. Secondary uranium recovery is from acid leaching the copper concentrate, which then goes on to be smelted, containing about 45% copper and up to 0.15% uranium. At present smelting is done at Olympic Dam, followed by electro refining, and the further traces of uranium are recovered at these stages.

The proposal then became to export much of the copper concentrate with enough uranium still present to require the application of non-proliferation safeguards, so that it was all accounted for. Hence smelting could only be undertaken in one of 36 countries with which Australia has a bilateral safeguards agreement, plus the heavy industry infrastructure required. China is the prime destination and could build dedicated facilities, as could Japan.

With eventually two-thirds of the copper concentrate from the expanded Olympic Dam operation being exported as concentrate, up to 2000 tonnes of uranium would be involved annually. The major part of the uranium – about 14,400 t/yr – would be recovered and processed as at present. This copper concentrate export strategy for the expanded production from Olympic Dam would diminish the investment cost of the expansion, since smelting and refining for most of the copper increment would not be required. The infrastructure needed at Olympic Dam to operate it – notably electricity – would also be less. A new smelter in China or Japan would be lower cost. However, unless it was owned and operated by BHP Billiton itself, there would be no flexibility in concentrate sales.

Plans for expansion of the mine would mean that 800,000 t/yr of copper concentrate derived from the higher-grade ore would be smelted onsite to produce 350,000 t/yr of refined copper product, and 1.6 million tonnes would be exported to be smelted in China or Japan to yield about 400,000 tonnes of refined copper. This lower-grade portion (mostly chalcopyrite – $CuFeS_2$) would have up to 2000 t of uranium in it (not more than 15% of total uranium) to be recovered there. Total uranium production would then be 14,400 tU from the hydrometallurgical plant onsite and 1700 tU from the exported concentrates, total 16,100 tU (19,000 t U_3O_8) per year. Gold production would be 25 tonnes per year.

Uranium and Nuclear Power in Kazakhstan

(Updated October 2017)

- **Kazakhstan has 12% of the world's uranium resources and an expanding mining sector, producing about 24,575 tU in 2016, but then reducing slightly.**
- **In 2009 it became the world's leading uranium producer, with almost 28% of world production, then 33% in 2010, rising to 41% in 2014, and 39% in 2015 and 2016.**
- **A single Russian nuclear power reactor operated from 1972 to 1999, generating electricity and desalinating water.**
- **Kazakhstan has a major plant making nuclear fuel pellets and aims eventually to sell value-added fuel rather than just uranium. A fuel fabrication plant is being built with 49% Chinese equity.**
- **The government is committed to a high level of uranium exports, and was planning to build a Russian nuclear power reactor probably at Kurchatov by 2025.**

Kazakhstan has been an important source of uranium for more than 50 years. Over 2001 to 2013 production rose from 2022 to about 22,550 tonnes U per year, making Kazakhstan the world's leading uranium producer. Mine development has continued with a view to further increasing annual production by 2018. Capacity is around 25,000 tU/yr, but in October 2011 Kazatoprom announced a cap on production of 20,000 tU/yr, which was evidently disregarded. Of its 17 mine projects, five are wholly owned by Kazatomprom and 12 are joint ventures with foreign equity holders, and some of these are producing under nominal capacity. In 2016, 12,986 tU was attributable to Kazatomprom itself – 21% of world production, putting it ahead of Cameco, followed by Areva and ARMZ-Uranium One. The country's total production in 2016 was 24,575 tU. In January 2017 Kazatomprom said that production would be reduced by about 10%, due to low prices.

Kazakhstan has northern and southern electricity grids with some connection, and links to Russia and Kyrgystan and Uzbekistan respectively. Electricity production was 91 TWh in 2015, 74 TWh (81%) from coal and gas thermal, 7 TWh from gas turbine, 9 TWh from hydro and 0.2 TWh from wind, according to KEGOC (Kazakhstan Electricity Grid Operating Company). Net imports from Russia was 471 GWh, net exports to Kyrgystan was 421 GWh. In 2015 capacity was 21 GWe with 17.5 GWe available, but maximum output was 12.5 GWe. In 2012 the government's energy system development plan had 150 TWh/yr production in 2030, with 4.5% of this from nuclear and 10% from renewables. The government planned investment in electricity production and grid of $7.8 billion by 2015, and foresees $64 billion by 2030.

Future electricity demand will depend to some extent on the country's role from 2019 in the Eurasian Economic Community energy market. Also the State Grid Corporation of China (SGCC) is planning transmission links from China. The state-owned Kazakhstan Electricity Grid Operating Company (KEGOC) was set up in 1997. The question of nuclear power in Kazakhstan has been discussed for many years, notably since 2006 with Russia, and a national nuclear strategy is expected in 2018.

Kazatomprom is the national atomic company set up in 1997 and owned by the government. It controls all uranium exploration and mining as well as other nuclear-related activities, including imports and exports of nuclear materials. It announced in 2008 that it aimed to supply 30% of the world's uranium by 2015 (it produced 39% in fact), and through joint ventures: 12% of the uranium conversion market, 6% of enrichment, and 30% of the fuel fabrication market by then.

Prior to Kazatomprom's establishment, other arrangements pertained for uranium development. One of these was with Canada-based World-Wide Minerals Ltd (WWM), under a 1989 bilateral investment treaty between Canada and the USSR.*

* WWM invested heavily in the country over 1996-97, upgrading and operating the Tselinny (TGK) uranium mining and processing facilities at Stepnogorsk, with an option to acquire 90% equity in them as well as developing additional mines. WWM and subsidiaries entered into agreements with the Kazakh government, but claims that the government frustrated its endeavours, leading to a loss of more than $50 million and its exit from the country. In January 2016 an international arbitral tribunal upheld WWM's claims under investor-state arbitration and dismissed Kazakh objections. WWM is seeking $5 billion settlement.

International collaboration

Kazatomprom has forged major strategic links with Russia, Japan and China, as well as taking a significant share in the international nuclear company Westinghouse. Canadian and French companies are involved with uranium mining and other aspects of the fuel cycle.

Russia

In July 2006 Russia and Kazakhstan (Kazatomprom) signed three 50:50 nuclear joint venture agreements totalling US$ 10 billion for new nuclear reactors, uranium production and enrichment. The first JV with Atomstroyexport is JV Atomniye Stantsii for development and marketing of innovative small and medium-sized reactors, starting with OKBM's VBER-300 as baseline for Kazakh units. Russia's Atomstroyexport expected to build the initial one.

The second JV with Tenex, confirmed in 2008, is for extending a small uranium enrichment plant at Angarsk in southern Siberia (this will also be the site of the first international enrichment centre, in which Kazatomprom has a 10% interest). It will eventually be capable of enriching the whole 6000 tonnes of uranium production from Russian mining JVs in Kazakhstan. See Fuel Cycle section below.

The uranium exploration and mining JVs Akbastau and Karatau with Tenex started with Budenovskoye in the Stepnoye area of south Kazakhstan, which commenced production in 2008. These complemented the Zarechnoye JV 250 km to the south which was set up in June 2006. However, in 2009 and 2010 the 50% ARMZ equity in these three was traded for an eventual 51% share of Canadian-based Uranium One Inc, which subsequently became wholly-owned by ARMZ. Uranium One Holdings (U1H) is now the holding company for all Russian uranium mining interests in Kazakhstan (and its equity in an acid plant).

In March 2011 Russia and Kazakhstan (Kazatomprom) signed stage II of this 2006 integrated cooperation program, involving uranium exploration and a feasibility study for a Kazakh nuclear power plant. Under this, and following JV development at Angarsk, Kazatomprom bought a 25% share of Russia's Novouralsk enrichment plant in 2013. (Separately, Kazatomprom has a 10% share in the International Uranium Enrichment Centre – IUEC – at Angarsk.)

At the end of May 2014 several agreements were signed between Rosatom and NAC Kazatomprom. One was a MOU for construction of a nuclear power plant using VVER reactors and with capacity up to 1200 MWe. It also involved fuel fabrication and nuclear waste management. A second agreement related to uranium mining at Kharasan-1, Akdala and South Inkai, where ARMZ has equity through Uranium One. A third agreement was a Comprehensive Development Program for Russia-Kazakhstan Cooperation in the Peaceful Uses of Atomic Energy, for nuclear power and fuel cycle matters.

Japan

In April 2007 a number of high-level agreements on energy cooperation were signed with Japan. These included some relating to uranium supply to Japan, and technical assistance to Kazakhstan in relation to fuel cycle developments and nuclear reactor construction. A further agreement on uranium supply and Japanese help in upgrading the Ulba fuel fabrication plant was signed in may 2008. Kazatomprom is keen to move from being a supplier of raw materials to selling its uranium as fabricated fuel assemblies. It said that it aimed to supply 40% of the Japanese market for both natural uranium and fabricated fuel from 2010 – about 4000 tU per year. Negotiations then commenced for a bilateral nuclear cooperation agreement between Kazakhstan and Japan. In May 2011 a high-level intergovernmental agreement on developing nuclear energy was signed.

In August 2006 The Japan Bank for International Cooperation had signed an agreement with Kazatomprom to support and finance Japanese firms in developing Kazakh uranium resources to supply Japan's power generation. In April 2007 several Japanese companies – the Energy Asia consortium – bought 40% of the whole Kharasan mine project. Initially, Energy Asia comprised Marubeni 55%, Tepco 30%, Chubu 10% and Tohoku 5%. When Toshiba agreed to sell part of Westinghouse to Kazatomprom, it agreed to buy 9% of Kharasan from Marubeni (*i.e.* 22.5% of the Japanese stake). Then Kyushu Electric Power Co bought 2.5% of the Japanese stake, leaving Marubeni with 30%. The Energy Asia consortium share involved with both JVs (Kyzylkum and Baiken-U) became: Marubeni 30%, Tepco 30%, Toshiba 22.5%, Chubu 10%, Tohoku 5% and Kyushu 2.5%.

In March 2009 three Japanese companies – Kansai, Sumitomo and Nuclear Fuel Industries – signed an agreement with Kazatomprom on uranium processing for Kansai plants. In March 2010 a joint venture with Sumitomo was set up: Summit Atom Rare Earth Company, and in June, Kazatomprom and Toshiba Corp. agreed to set up a rare earth metals joint venture.

In September 2010, based on an April 2007 agreement, Japan Atomic Power Co, Toshiba and Marubini signed a technical cooperation agreement with the National Nuclear Centre (NNC) to study the feasibility of building nuclear power capacity. A further agreement to this end was signed in February 2013, between Japan Atomic Power Co (JAPC) and Marubini Utility

Services, with NNC (see section below). At the same time an agreement between NNC and the Japan Atomic Energy Agency (JAEA) with JAPC concerned mining and processing of uranium and rare earth minerals. In October 2015 a further agreement between Kazatomprom, JAPC and Marubini Utility Services was signed, to develop cooperation on construction and financing of a nuclear power plant, involving consultations, exchange of experience in public communications, organization of technical workshops and meetings of experts on security and the training of staff.

In June 2012 and February 2013 R&D agreements between NNC and JAEA were signed relating to the design, construction and operation of the Kazakhstan high-temperature gas-cooled reactor (HTR) of about 50 MW at Kurchatov. This is flagged as a national project.

In June 2015 an agreement was signed between NNC and JAEA for stage 3 of a project to investigate sodium-cooled fast reactors in Kazakhstan.

China

In December 2006 China Guangdong Nuclear Power Group (now China General Nuclear Corporation - CGN) signed a strategic cooperation agreement with Kazatomprom, in May 2007 an agreement on uranium supply and fuel fabrication, and in September 2007 agreements on Chinese participation in Kazakh uranium mining joint ventures and on Kazatomprom investment in China's nuclear power industry. This is a major strategic arrangement for both companies, with Kazatomprom to become the main uranium and nuclear fuel supplier to CGN (accounting for a large share of the new reactors being built in China). In October 2008 a further agreement was signed covering cooperation in uranium mining, fabrication of nuclear fuel for power reactors, long-term trade of natural uranium, generation of nuclear electricity and construction of nuclear power facilities. In December 2014 a further agreement was signed with similar scope but focused on establishing a joint venture in Kazakhstan for the production of 200 t/yr of fuel assemblies. In December 2015 a further agreement was signed on the fuel fabrication project, to be at the Ulba Metallurgical Plant (see Fuel cycle: front end section below). A CGN subsidiary, Sino-Kazakhstan Uranium Resources Investment Co, has invested in two Kazakh uranium mines, Irkol and Semizbai, through the Semizbai-U LLP joint venture. In 2015 CGN Mining Co bought the 49% Chinese equity in Semizbai-U.

A framework strategic cooperation agreement was signed with China National Nuclear Corporation (CNNC) in September 2007 and this was followed in October 2008 with another on "long-term nuclear cooperation projects" under which CNNC was to invest in a uranium mine. Late in 2007 Kazatomprom signed an agreement with both GCNPC (now CGN) and CNNC for them to take a 49% stake in two uranium mine joint ventures and supply 2000 tU per year from them. In February 2011 CNNC signed a contract to buy 25,000 tU.

Early in 2009 Kazatomprom signed an agreement with CGNPC for establishment of a specialized company for the construction of nuclear power plants in China, since Kazakh plans to work with Russia's Atomstroyexport developing and marketing innovative small and medium-sized reactors had been put on hold. In mid-2009 a feasibility study on this joint CGNPC project was underway, but no more has been heard since. In December 2015 both governments announced the establishment of a $2 billion fund for bilateral projects within the framework of the 'New Silk Road', now Belt & Road Initiative (BRI), the new Chinese investment program. CGN is working with Kazatomprom to build the Ulba-FA fuel fabrication plant.

In mid-2014 Kazatomprom said that 55% of Kazakh uranium production was exported to China.

At the end of August 2015, among $23 billion of China-Russia deals, JSC Samruk-Kazyna, the national holding company owning NAC Kazatomprom, signed deals worth $5 billion with Chinese companies and Kazatomprom agreed on transit of its products via China to North America.

In 2013 China agreed to a $5 billion stake in the new Kashagan oil project, trumping a bid from India, and underlining China’s Central Asian resource aspirations.

The Samruk-Kazyna Wealth Fund, with assets of over $64 billion, plans initial public offerings in 2018, including one for Kazatomprom, to reduce its holdings in several state enterprises.

India

In January 2009 Kazatomprom signed an agreement with India's Nuclear Power Corporation (NPCIL) to supply 2100 tonnes of uranium to India and undertake a feasibility study on building Indian PHWR reactors in Kazakhstan. NPCIL said that it represented "a mutual commitment to begin thorough discussions on long-term strategic relationship." Under this agreement, 300 tonnes of natural uranium will be supplied by Kazatomprom in the 2010-11 year.

In April 2010 Kazakhstan signed a nuclear cooperation agreement with South Korea, paving the way for export of Korean

SMART 100 MWe nuclear reactors and for joint projects to mine and export Kazakh uranium.

In addition Kazakhstan has signed intergovernmental agreements on nuclear energy cooperation with the USA and Euratom.

South Korea

The Kazakh Industry and Trade Ministry has held talks with South Korea's KEPCO, (Korea Electric Power Corporation) on uranium mining and nuclear power plant construction in Kazakhstan, apparently on KEPCO's initiative.

Toshiba

At the corporate level, in 2007 Kazatomprom purchased a 10% share in Westinghouse. Toshiba had bought the company from BNFL for $5.4 billion early in 2006, and The Shaw Group then took 20% and IHI Corp. 3%. Toshiba originally envisaged holding only 51%, and this deal reduced its holding to 67%. The Kazatomprom link strengthened the company's upstream links for fuel supplies, and was to enhance its marketing of nuclear reactors (the vendor usually supplies the first core for a new reactor, and ongoing fuel services may be offered in addition). It also brought Kazatomprom more fully into the industry mainstream, with fuel fabrication in particular. However, in 2017 Kazatomprom exercised its option to require Toshiba to buy its share for $522 million

The Westinghouse link led to a decision to set up with Toshiba a nuclear energy institute in the northeastern town of Kurchatov, near Semipalatinsk, which is already a centre of R&D activity. This was announced by Kazatomprom and the Kazakh prime minister in September 2008 and was to focus on skills development in all aspects of the nuclear fuel cycle as well as reactor technology. Other Japanese companies such as Toyota and Marubeni were expected to support the institute, especially in its rare earth metals department which aims to utilise present waste materials as the basis of a billion-dollar high-tech export industry. Three research reactors are operated by the Institute of Atomic Energy at Kurchatov.

Canada, Cameco

In May 2007 Canada's Cameco Corporation signed an agreement with Kazatomprom to investigate setting up a uranium conversion plant, using its technology, and also increasing uranium production at its 60% owned Inkai mine.

In May 2016 Cameco and Kazatomprom agreed to restructure the Inkai JV, extending it to 2045 but with Cameco becoming a minority owner, with 40%. Production is to be ramped up to 4000 tU per year by about 2021.

In June 2008 Cameco and Kazatomprom announced the formation of a new company – Ulba Conversion LLP – to build a 12,000 t/yr uranium hexafluoride conversion plant at the Ulba Metallurgical Plant (UMZ) in Ust-Kamenogorsk. Cameco would provide the technology and hold 49% of the project. A preliminary feasibility study was undertaken jointly by Kazatomprom and UMZ, then the project was put on hold. In mid-2013 Cameco announced that subject to a feasibility study, construction of 6000 t/yr capacity would start in 2018, for 2020 operation. A May 2016 agreement grants Kazatomprom a five-year option to license Cameco's uranium conversion technology for constructing and operating a uranium conversion plant in Kazakhstan.

In December 2013, a prefeasibility study (PFS) for a uranium refinery in Kazakhstan was completed, to produce UO_3 for further processing in Canada. The project will require government approvals for the transfer of Cameco's proprietary uranium refining technology from Canada. In January 2014 the government referred to the proposed plant as a 'strategic goal', and in May 2016 the two companies agreed to complete a feasibility study on a uranium refinery producing 6000 tU per year as UO_3. This would initially be owned 71.67% by Kazatomprom and 28.33% by Cameco, and Cameco's interest in JV Inkai would increase from 40% to 42.5% on commissioning of the refinery. Should the refinery be built, Kazatomprom will also be given an option to obtain UF6 conversion services at Cameco's Port Hope facility and to receive other commercial support from Cameco, whose equity in both operations might increase slightly as a result.

In November 2013 Canada and Kazakhstan signed a nuclear cooperation agreement.

USA, Centrus, Converdyn

In October 2015 Kazatomprom signed an agreement with Centrus Energy to help market Kazakh uranium in the USA.

In April 2016 Kazatomprom signed an agreement with US-based Converdyn so that Kazatomprom could offer uranium for sale in the form of natural UF_6, and access new markets with an "integrated product offering", giving customers "increased supply options". This is simply a marketing alliance, complementary to the Cameco investment in Ulba.

Also in April a Kazakh-US energy partnership agreement was signed, related to nuclear security and in particular the "conversion of Kazakhstan's research reactors and enforcement of physical nuclear security."

Areva

In June 2008 Areva signed a strategic agreement (MOU) with Kazatomprom to expand the existing Katco joint venture from mining 1500 tU/yr to 4000 tU/yr (with Areva handling all sales), to draw on Areva's engineering expertise in a second JV (49% Areva) to install 1200 tonnes per year fuel fabrication capacity at the Ulba Metallurgical Plant, and in a third JV (51% Areva) to market fabricated fuel.

In October 2009 the two parties signed another agreement to establish the IFASTAR joint venture (Integrated Fuel Asia Star - 51% Areva) to establish the feasibility of marketing an integrated fuel supply for Asian customers (ie selling the enriched and fabricated fuel, not simply Kazakh uranium or Areva front-end services), and of building a 400 t/yr nuclear fuel fabrication line at the Ulba plant. IFASTAR is to be based in Paris, and would market the fuel.

In October 2010 an agreement was signed to set up a joint venture company (51% Kazatomprom) to build a 400 t/yr fuel fabrication plant based on an Areva design at the Ulba Metallurgical Plant, starting operation by 2014. In November 2011 a further agreement was signed in relation to the plant. In March 2016 Areva was awarded a contract for equipment and support to the Ulba-FA plant for the fabrication of 200 t/yr of fuel assemblies for China General Nuclear Corp (CGN) reactors. The plant is being built by a Kazatomprom-CGN joint venture.

In April 2017 a further agreement with Areva was signed to give the Katco joint venture a new long-term perspective, with the development of the South Tortkuduk (Moinkum?) project.

Iran

In March 2017 Kazatomprom contracted to supply 950 t of uranium concentrate to Iran over three years, subject to agreement by the UN Security Council.

Mines

At a corporate and project level in mining, the following table summarises international equity links:

Company, project or mine	Foreign investor and share	Value of share or project if known
Inkai JV (Inkai mines)	Cameco 60% (to become 40%)	
Betpak Dala JV (South Inkai, Akdala mines)	Uranium One 70%	$350 million for 70% in 2005
Appak JV (W.Mynkuduk)	Sumitomo 25%, Kansai 10%	$100 million total in 2006
JV Karatau (Budenovskoye 2 deposit)	Uranium One 50% (bought from ARMZ in 2009)	117 million Uranium One shares (giving 19.9% ownership) + $90 million
Akbastau JSC (Budenovskoye 1, 3, 4 deposits)	Uranium One 50% (bought from ARMZ in 2010)	
Zhalpak	CNNC 49%	
Katco JV (Moinkum, Tortkuduk mines)	Areva 51%	$110 million in 2004
Kyzylkum JV (Kharasan 1 mine)	Uranium One 30%, Energy Asia (Japanese) 40%	$75 million in 2005 for 30%, $430 million total in 2007 (both mines)
Baiken-U JV (Kharasan 2 mine)	Energy Asia (Japanese) 95%	$430 million total in 2007 (both mines)
Semizbai-U JV (Irkol, Semizbai mines)	CGN 49%, also CNEIC	
Zarechnoye JSC (Zarechnoye & S.Zarechnoye mines)	Uranium One 49.67% (bought from ARMZ in 2010), Krygyzstan 0.66%	ARMZ paid $60 million total

Early in 2012 Kazatomprom announced that it would increase its share in mining activities nationally from 46% to 51% by buying out Japanese (and possibly some Uranium One) equity in the Kyzylkum and Baiken-U JVs, where it currently holds 30% and 5% respectively. Both JVs are mining the Kharasan deposit in the western part of Syrdarya province.

In 2009 investigations were launched into how, and at what prices, certain Kazakh entities came to hold title to particular mineral deposits before those rights were sold to international investors, particularly some of those above. In June 2009 Kazatomprom reassured its foreign joint venture and equity partners in uranium mining, from Japan, Russia, Canada, France and China that existing arrangements with foreign partners would not be changed, despite criminal charges being laid against former Kazakh executives.

The transfer to Uranium One of ARMZ's half shares in Akbastau and Zarechnoye (valued at US$ 907.5 million) in 2010 involved payment by ARMZ of US$ 610 million in cash (at least US$ 479 million of which would be paid directly to shareholders – other than ARMZ – as a change of control premium) and ARMZ increasing its shareholding in Uranium One from 23% to at least 51.4% through a share issue. It subsequently took over the whole company.

Uranium trading

In April 2017 Kazatomprom announced the formation of a Swiss-based trading subsidiary TH Kazatom, to bring greater liquidity to the uranium market from late in the year. It will buy and sell on the spot market as part of its corporate transformation to align its pricing mechanism with “the way our customers want to buy”, especially in European and US markets.

Uranium mining

Uranium exploration started in 1948 and economic mineralisation was found is several parts of the country and this supported various mines exploiting hard rock deposits. Some 50 uranium deposits are known, in six uranium provinces. Reasonably Assured Resources plus Inferred Resources to US$ 130/kgU were 679,000 tU in 2013.

In 1970 tests on in situ leach (ISL) mining commenced and were successful, which led to further exploration being focused on two sedimentary basins with ISL potential.

In-situ leaching is a low-impact method of mining (Kazatomprom)

Up to 2000 twice as much uranium had been mined in hard rock deposits than sedimentary ISL, but almost all production is now from ISL. Uranium production dropped to one-quarter of its previous level 1991 to 1997, but has since increased greatly.

Kazakh Uranium Production and Revenue

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Tonnes U	2022	2709	2946	3712	4362	5281	6637	8521	14020	17803	19450	21317	22548	22829	23800
Revenue	19954	23822	28330	36849	50567	89422									

Source: Kazatomprom, currency KZT million

In 2009 Kazakhstan became the world's leading source of mined uranium, producing almost 28% then, 33% in 2010, 36% in 2011, 36.5% in 2012 and 38% in 2013.

Kazakh Uranium Production by Mines (tonnes U)

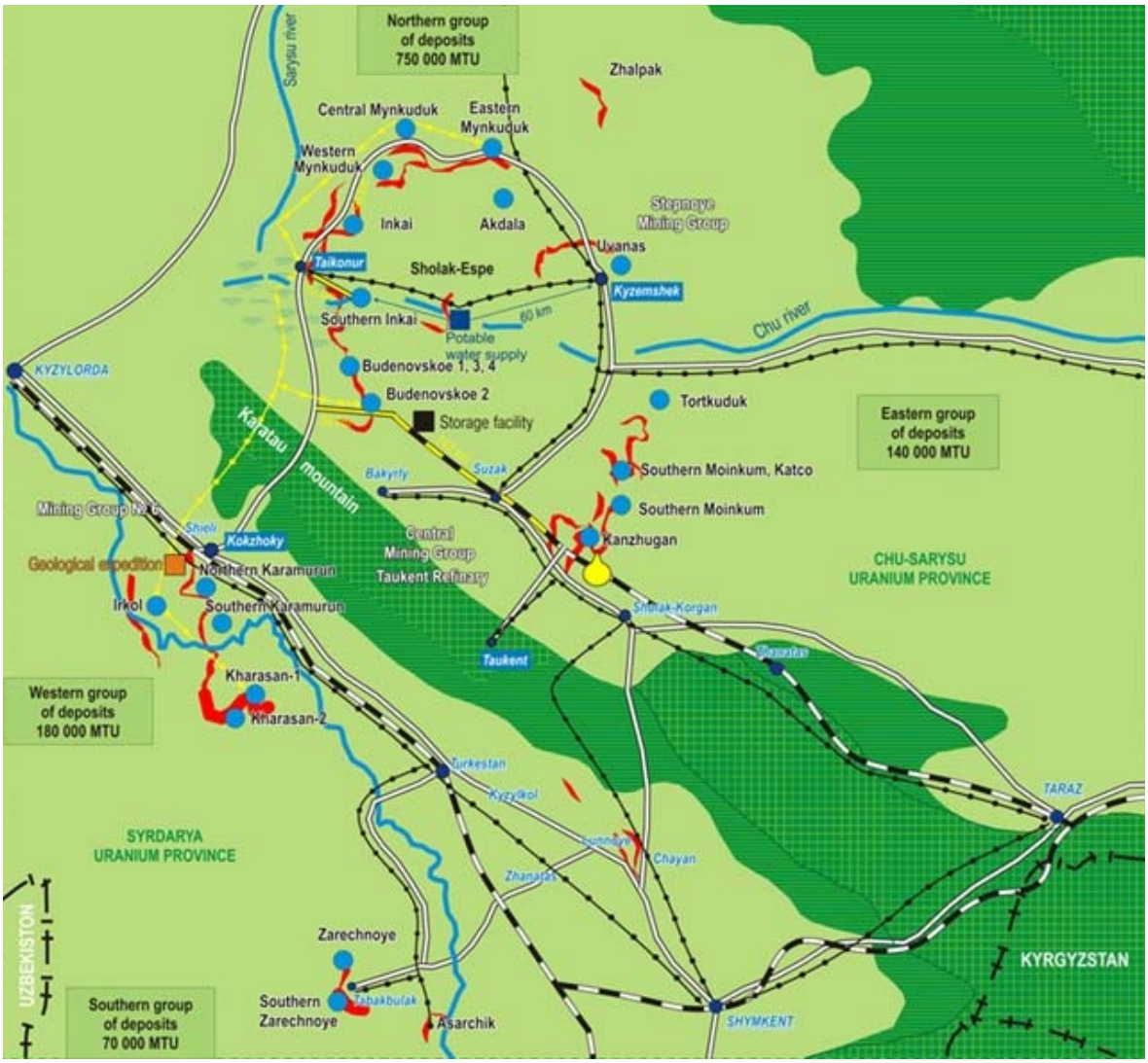
Province and Group	Mine	2012	2013	2014	2015	2016	2017
Chu-Sarysu, Eastern	Tortkuduk & northern Moinkum (Katco)	3661	3558	4322	4109	4002	3510 plan
	Southern Moinkum & Kanzhugan (Taukent/GRK)	1075	1129	1174	1192	793	
Chu-Sarysu, Northern	Uvanas & Eastern Mynkuduk (Stepnoye-RU/GRK)	1234	1192	1154	1154	1244	
	Central Mynkuduk (Ken Dala.kz)	1622	1800	1790	1847	2010	
	Western Mynkuduk (Appak)	1003	998	870	1000	1004	
	Inkai-1, 2, 3 (Inkai)	1701	2047	1922	2234	2291	
	Inkai-4 (South Inkai)	1870	2030	2002	2055	2056	
	Akdala (Betpak Dala)	1095	1020	1007	1019	1001	
	Budyonovskoye 1, 3 (Akbastau)	1203	1499	1594	1642	1743	
	Budyonovskoye 2 (Karatau)	2135	2115	2084	2061	2081	
Syrdarya, Western	North and South Karamurun (GRK)	1000	1000	941	948	1000	
	Irkol (Semizbai-U)	750	750	700	750	755	
	Kharasan 1 (Kyzylkum)	583	752	858	1110	1404	
	Kharasan 2 (Baiken-U)	603	888	1135	1400	1838	
Syrdarya, Southern	Zarechnoye (Zarechnoye)	942	931	876	826	828	
Northern, Akmola region	Semizbay (Semizbai-U)	470	411	400	453	511	
	RU-1 (Vostok, Zvezdnoye)	370	331	298	0	0	
TOTAL		21,317	22,451	23,127	23,800	24,560	

Some figures estimated.

The last surviving underground mines at Grachev and Vostok in the **Northern province** had been operating since 1958 and are now rather depleted. KazSabton operated them, having taken over from Tselinny Mining & Chemical Co (TGK) in 1999. It treated the ore at the Stepnogorsk mill, yielding some 250 tU per year. Production from the Stepnogorsk Mining & Chemical Complex plant at some 300 tU/yr has been the only non-ISL production, but the mine was reported to be shut down in 2015. The Semizbai ISL project is also in the Northern province, Akmola region, and Semizbai-U was formed in 2006 to mine it.

In the **Balkash province** some mining of volcanogenic deposits occurred during the Soviet era. In the **Ili province** east of this there is some uranium in coal deposits.

In the **Caspian province** the Prikaspisky Combine operated a major mining and processing complex on the Mangyshalk Peninsula in the 1960s and this led to the founding of Aktau. It was privatised as Kaskor in 1992 and operations ceased in 1994.



Map from Kazatomprom, 2007

All except one of the operating and planned ISL mine groups are in the 40,000 square kilometre **Chu-Sarysu province** in the central south of the country and controlled by the state corporation Kazatomprom. Mines in the Stepnoye area have been operating since 1978, some in the Tsentralnoye area since 1982 – both in the **Chu-Sarysu basin**/uranium district, which has more than half the country's known resources. It is separated by the Karatau Mountains from the **Syrdarya basin**/uranium district to the south, where mines in the Western (No.6) area have operated since 1985. All have substantial resources.

The ISL mines and projects in the two central southern provinces are in four groups, as set out below. Production costs from these are understood to be low. Mining is at depths of 100-300 metres, though some orebodies extend to 800 metres. Uranium One in September 2007 was quoting "cash cost" figures of $8.00 to $10.50/lb for three mines it is involved with, though these may not include wellfield development and current figures are quoted below. A further feature of Kazakh uranium mining is that Kazatomprom plans to establish new mines in three years, compared with twice this time or more in the West, due to regulatory hurdles.

Inkai is the largest ISL mine, and Cameco's description of its operation is: Uranium occurs in sandstone aquifers as coatings on the sand grains at a depth of up to 300 metres. Uranium is largely insoluble in the native groundwater which is not potable due to naturally high concentrations of radionuclides and dissolved solids. Using a grid of injection and production wells, a mining solution containing an oxidant (sulfuric acid) is circulated through the orebody to dissolve the uranium. The uranium-bearing solution (generally containing less than 0.1% uranium) is then pumped to a surface processing facility where the uranium is removed using ion exchange resin. The water is re-oxidized and re-injected into the orebody. The uranium is stripped from the resin, precipitated with hydrogen peroxide and then dried to form the final product, U_3O_8. This process is repeated to remove as much uranium as is economically feasible. When mining at the site is complete, the groundwater will be restored to its original quality.

This is a closed loop recirculation system since the water from the production well is reintroduced in the injection wells. Slightly less water is injected than is pumped to the surface to ensure that fluids are confined to the ore zones intended for extraction. Monitor wells are installed above, below and around the target zones to check that mining fluids do not move outside a permitted mining area.

Acid production

ISL uranium production in Kazakhstan requires large quantities of sulfuric acid*, about 1.5 million tonnes per year (according to Argus Media), due to relatively high levels of carbonate in the orebodies. A fire at a sulfuric acid production plant in 2007 led to shortages, and due to the delayed start-up of a new plant, rationing continued until mid-2008. Extra supplies were sought from Uzbekistan and Russia, but uranium production well into 2009 was affected. Uranium One revised its 2008 production downwards by 1080 tU, which it said was "primarily due to the acid shortage" for its South Inkai and Kharasan 1 projects (70% and 30% owned respectively) which were just starting up. In August 2009 Cameco reported that production at Inkai would remain constrained through 2009 due to acid shortage.

* 70-80 kg acid/kgU (comprising 15-20% of the operating expense), compared with Beverley and Four Mile in Australia at around 3 kg/kgU.

At Balkhash a 1.2 million t/yr Canadian acid plant feeding from the Kazakhmys Corporation copper smelter started production at the end of June 2008, financed by an EBRD loan to abate sulfur dioxide emissions from copper smelting. Another Kazakhmys metallurgical acid plant is at Zhezkazgan, with unknown capacity and old plant may not be operational.

A 180,000 t/yr Italian-built acid plant at the Stepnogorsk Mining and Chemical Combine costing $74 million was commissioned in 2015 to serve ISL mining. A 360,000 t/yr acid plant at Stepnogorsk started in 2008 but has apparently been shut down for environmental reasons.

Another new acid plant of 500,000 t/yr capacity, was commissioned in December 2011 at Zhanakorgan, next to the Kharasan mines in the Western (#6) mining group or Kyzlorda region, to serve those mines from 2011, reaching design capacity in 2012. In 2013 it produced 356,600 t of acid and 16.9 MWh of power. At full capacity it burns 170,000 t/yr of solid sulfur derived from oil and gas production by Tengizhevroil in western Kazakhstan. This is the SKZ-U LLP/SAP-U* joint venture, with Kazatomprom (49%), Japanese interests (32%) and Uranium One (19%). It is a US$ 216 million project, and supplies all the Western region mines: Kharasan, Irkol and Karamurun.

* Construction of the plant was being carried out by SKZ-U LLP joint venture, in which Baiken-U LLP (40%) and Kyzylkum LLP (60%) are the stakeholders. Uranium One declares a 19% "joint control interest" in SKZ-U from 2009.

KazZinc has a 320,000 t/yr metallurgical acid plant operating since 2004 at Ust-Kamenogorsk Metallurgical Complex, taking gas from a zinc roaster and lead smelter, and another of unknown capacity operating there since 2011, taking gas from an IsaSmelt lead furnace. Both are primarily to abate sulfur dioxide emissions from smelting.

A further acid plant of 180,000 t/yr capacity is planned in connection with the Pavlodar Oil Refinery in northeast Kazakhstan, using 60,000 t/yr of sulfur from the refinery.

In 2009 Kazatomprom with other mining companies and two acid producers, KazZinc JSC and Kazakhmys, set up a coordinating council to regulate acid supplies and infrastructure. Cameco reported that acid supply was adequate through 2010.

Kazakh ISL uranium mines

Region	ISL Mine	Resources tU	Operator	Annual production target tU/yr	Start production, full prod'n
Chu-Sarysu Province, Chu-Sarysu district					
Northern/Stepnoye group	Uvanas	8100	Stepnoye-RU LLP (K'prom)	400	2006
	East Mynkuduk	22,000		1300	2006, 2007

Region	ISL Mine	Resources tU	Operator	Annual production target tU/yr	Start production, full prod'n
	Inkai 1, 2, 3	reserves 31,000 tU, plus 54,350 tU measured & indicated resources and 33,000 tU inferred		2500 in 2017, 4000 later	2008, 2010, 2019 for expansion
	South Inkai (Inkai 4)	Reserves 13,000, in 15,260 indicated, 17,100 inferred	BetpakDala JV: Uranium One 70%, K'prom 30%	2000	2007, 2011
	Akdala	10,359 total		1000	2006, 2007
	Central Mynkuduk (Mynkuduk)	52,000	JSC Ken Dala.kz Stepnogorsk (K'prom), Production Enterprise Ortalyk from 2011	2000	2007, 2010
	West Mynkuduk	26,000	Appak JV: K'prom 65%, Sumitomo 25%, Kansai 10%	1000	2008, 2010
	Akbastau (Budenovskoye 1, 3, 4)	31,600 reserves, in 47,293 resources	JV Akbastau: K'prom 50%, Uranium One 50%	1000 (1) 2000 (3,4)	2009, 2015 2010
	Karatau (Budenovskoye 2)	52,000 reserves, in 64,000 resources	JV Karatau: K'prom 50%, Uranium One 50%	2000 (to 3000)	2008, 2011
	Zhalpak	15,000	JV with China ?? (CNNC 49% was proposed)	500-1000	2017?
Central/Eastern (Tsentralnoye) group	Tortkuduk (Moinkum North)	24,000		2500	2007, 2008
	Moinkum* (southern Moinkum, Katco) - northern	in above	Katco JV, Areva 51%, K'prom 49%	1500	2006, 2007
	South Moinkum (east Moinkum) - southern	35,000	Taukent Mining & Chemical Plant LLP (K'prom)	1500	2006
	Kanzhugan / Kaynarski	22,000		600	2008
Chu-Sarysu Province, Syrdarya district					
Western (no.6) group	Kharasan 1 (north)	15,693 plus 17,940 inferred	Kyzylkum JV, Energy Asia 40%, Uranium One 30%, K'prom 30%	3000	2010, 2014
	Kharasan 2 (south)	?	Baiken-U JV, Energy Asia 95%, K'prom 5%	2000	2010, 2014
	Irkol	30,000	Semizbai-U JV (K'prom 51%, CGN Mining 49%)	750	8/2008, 2010
	N. Karamurun	16,000	Mining Group 6 LLP (K'prom)	1000	2007, 2010
	S. Karamurun	18,000	Mining Group 6 LLP (K'prom)	250	2009

Region	ISL Mine	Resources tU	Operator	Annual production target tU/yr	Start production, full prod'n
Southern group	Zarechnoye	12,500 plus 4500 inferred	Zarechnoye JV: K'prom 49.67%, Uranium One 49.67%	1000	2007, 2012
	Southern Zarechnoye	"insufficient to support development"		600	deferred
Northern Province					
Akmola region	Semizbai		Semizbai-U JV (K'prom 51%, CGN Mining 49%)	700	2009, 2011

Kazatomprom mining subsidiaries and joint ventures

Company or JV	Mines
Mining Company LLP (GRK) (Stepnoye-Ru LLP, Mining Group No.6 LLP)	Uvanas East Mynkuduk North & South Karamurun
GRK: Ken Dala.kz JSC	Central Mynkuduk
GRK: Taukent Mining-Chemical Plant LLP	Kanzhugan South Moinkum
Katco JV (with Areva 51%)	South Mynkuduk Moinkum 1&2 Tortkuduk
Inkai JV (with Cameco 60%, to become 40%)	Inkai 1, 2, 3
Zarechnoye JV (with Uranium One 49.67%)	Zarechnoye South Zarechnoye
APPAK JV (with Sumitomo 25% & Kansai 10%)	West Mynkuduk
Betpak Dala JV (with Uranium One 70%)	Akdala South Inkai
Karatau JV (with Uranium One 50%)	Karatau/Budenovskoye 2
Akbastau JV (with Uranium One 50%)	Akbastau/Budenovskoye 1, 3, 4
Kyzylkum JV (with Uranium One 30% & Energy Asia 40%)	(North) Kharasan 1
Baiken-U JV (with Energy Asia 95%)	(South) Kharasan 2
Semizbai-U JV (with CGN 49%)	Semizbai Irkol
Zhalpak JV (with CNNC 49%?)	Zhalpak

The mines and regions

Stepnoye or Northern mining group

The Stepnoye or Northern mining group in the Chu-Sarysu basin consists of Uvanas, East Mynkuduk, Akdala and Inkai mines, with Central and West Mynkuduk, South Inkai, Budenovskoye and Zhalpak planned. All are amenable to in-situ leaching (ISL).

Uvanas is a small deposit which commenced operation in 2006.

Inkai was discovered in 1976, and the Inkai Joint Venture (JVI) developed the Inkai mine in this part of the Chu-Sarysu basin and holds rights to blocks 1,2&3. JVI was set up in 1996 (then including Uranerz), and now Cameco holds 60% with Kazatomprom (40%). Following a two-year feasibility study completed in 2004, and regulatory approval in 2005, JVI started commercial production from ISL in 2008 and ramped up to 2000 tU/yr from blocks 1&2 – 2013 production was 1900 tU.

Eventual production is envisaged as 4000 tU/yr from all three blocks, and plans for this are agreed, involving a progressive change of ownership to 40% Cameco and 60% Kazatomprom with lease extension to 2045 from all three blocks. The agreement is linked to that for a uranium refinery, and Cameco's interest in JV Inkai could increase later to 44%.

JVI is developing block 3, and in 2015 started operation of the test wellfields there and began uranium production with the test leach facility. Production is not yet included in the JV totals.

Capital cost of the JVI development for the remaining life of current reserves at the end of 2016 were quoted at $297 million The main processing plant on block 1 has an ion exchange capacity of 1040 tU/yr and a product recovery capacity of 3100 tU/yr. A satellite 2400 tU/yr IX plant is on block 2, and a test leach facility on block 3. Cameco has reported for blocks 1&2: 36,600 t U_3O_8 proven and probable reserves at 0.057% grade plus 64,100 t measured & indicated resources at 0.057% grade and 39,000 t U_3O_8 inferred resources. Operating cost over the life of the mine is estimated to be $12.71 /lb U_3O_8. Cameco considers that block 3 "has the potential to support a commercial operation" but does not quote resource figures (end 2016, NI 43-101 technical report).

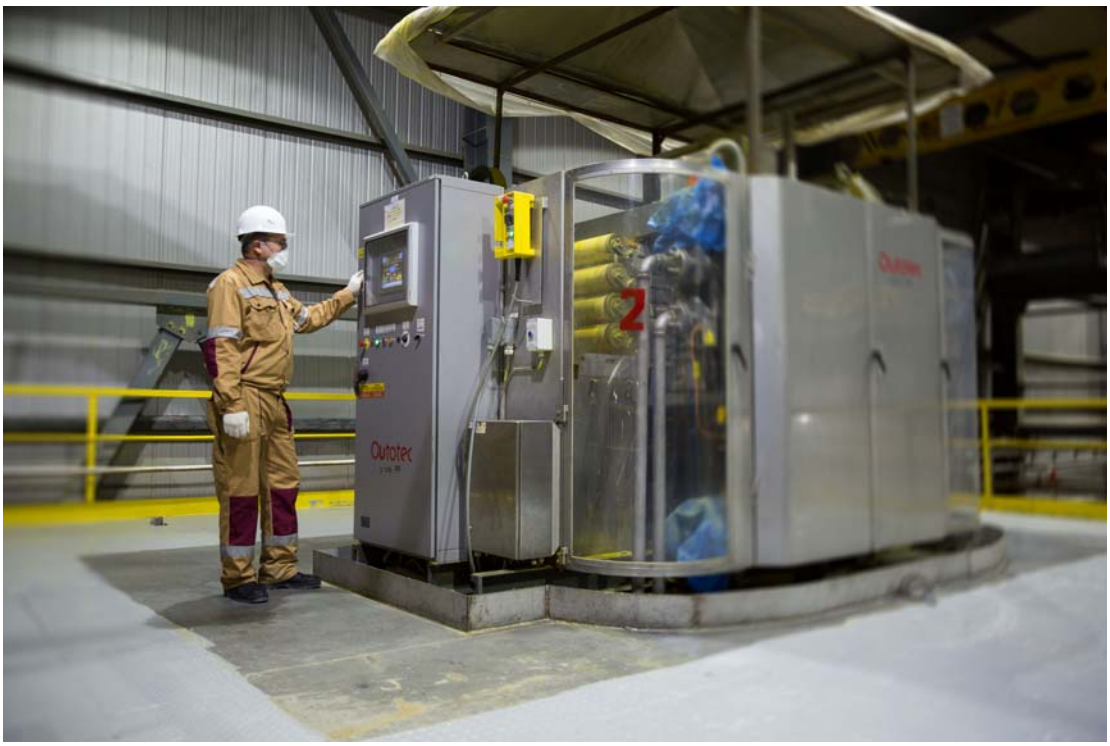
In September 2005 UrAsia Energy Ltd of Canada agreed to pay US$ 350 million for 70% of the **Betpak Dala** joint venture which owns the South Inkai project and the Akdala mine. The company (UrAsia) is now Uranium One Inc.

South Inkai mine started trial production in 2007 and was ramping up to expected 1900 tU/yr in 2011. Commercial production officially began in January 2009, and in that year 830 tU was produced. Cash operating cost in 2009 was $21/lb of concentrate, expected to drop to $19 in 2013, though significant capital requirement remains then.

South Inkai in mid-2013 has 5641 tU measured and indicated resources, 5077 tU proven and probable resources and 17,099 tU inferred resources. Average grade is 0.015%, 0.010% and 0.040% respectively. Uranium One projected average cash cost of production for 2014 as $18/lb U_3O_8.

Akdala started up in 2006 and produced 1031 tU in 2008 and 1046 tU in 2009, at cash operating cost of $14/lb of concentrate, expected to increase to $15 in 2013. In two orebodies Akdala in mid 2013 has 2286 tU measured & indicated resources, and 2058 tU proven & probable resources. Inferred resources are 6015 tU. Uranium One projected average cash cost of production for 2014 as $16/lb U3O8.

Central Mynkuduk mine started up in 2007 and was expected to reach capacity of 2000 tU/yr by 2010. It is operated by the Ken Dala.kz joint stock company, part of Kazatomprom (has been reported as Ortalyk LLP).



Production of yellowcake at Central Mynkuduk (Kazatomprom)

West Mynkuduk: Early in 2006 KazAtomProm signed a US$ 100 million joint venture agreement with Sumitomo Corp (25%) and Kansai Electric Power Co (10%) to develop the deposit. First production from the Appak JV was in June 2008 with design capacity of 1000 t/yr expected in 2010. Sumitomo will supply uranium from the mine to Japanese power utilities.

The **East Mynkuduk** mine was launched in May 2006 by Kazatomprom to achieve its planned 1000 t/yr production in 2007.

The **Karatau** mine at the south end of the **Budenovskoye** deposit started production in 2008 (655 tU), and ramped up to a capacity of 2000 tU/yr by 2011. Capacity of the Budenovskoye 2 uranium recovery plant reached 3000 tU/yr in 2011, serving both Karatau and Akbastau. Karatau in mid-2013 has reserves of 52,000 tU in measured and indicated resources of 63,839 tU and proven and probable resources of 51,960 tU. Average resource grade is 0.074% and 0.035% respectively. Uranium One projected average cash cost of production for 2014 as $11/lb U_3O_8. In 2016 wells were drilled to 700 metres and production tests commenced.

The **Akbastau** mine (Budenovskoye 1, 3, 4) just north of this started production at the end of 2009 and produced 385 tU that year, with recovery from pregnant liquor being at Karatau. It expected almost 1000 tU production in 2011 and ramping up to 3000 tU/yr by 2015, with $200 million being spent to achieve that. Akbastau 1-3 in mid 2013 have reserves of 31,600 tU, in combined measured and indicated resources of 47,293 tU, and proven and probable resources of 31,598 tU. Uranium One projected average cash cost of production for 2014 as $13/lb U_3O_8.

In July 2006 both Budenovskoye operations became 50:50 JVs with Russia, complementing Zarechnoye, but in 2009 ARMZ's share in Karatau was sold to Uranium One. In 2010 ARMZ's share in Akbastau was also transferred to Uranium One.

Zhalpak: A Chinese (CNNC)-Kazatomprom joint venture was set up to develop the deposit. This could produce up to 1000 tU/yr from resources of 15,000 tU.

Central or Eastern mining group

The Central or Eastern mining group (Tsentralnoye) in the Chu-Sarysu basin comprises Tortkuduk, Moinkum, Southern Moinkum, Kanzhugan mines, plus the new refinery. Katco operates the first two, Taukent the latter two.

Moinkum (Muyunkum): Following three years' pilot plant operation, Areva and the state utility Kazatomprom agreed in April 2004 to set up a 1500 tU/yr in situ leach (ISL) uranium venture at Moinkum in this part of the Chu-Sarysu basin. Areva holds 51% and funded the US$ 90 million Katco joint venture, having spent some US$ 20 million already since 1996. Operation began in June 2006.

Tortkuduk (Moinkum North) is also part of the Katco JV and produced over 2400 tU in 2010. A South Tortkuduk project was mentioned by Areva in 2017, but may refer to Moinkum.

A June 2008 agreement expanded the Katco joint venture from mining 1500 tU/yr to 4000 tU/yr and sets up Areva to handle all sales from it through to 2039. At the end of 2016 Areva quoted Katco indicated resources as 24,162 tU @ 0.1%U, and inferred resources of 14,112 tU @ 0.08%U, with more pending 'registration'. With production over 4000 tU/yr the Katco operation is the world's largest ISL mine.

The **Kanzhugan** deposit supports the Kaynar mine which started up in 2008. **South Moinkum** is also operated by Taukent Mining & Chemical Co, a 100% subsidiary of Kazatomprom. Production from the two is over 1100 tU/yr.

Western mining group (#6)

The Western mining group (#6) is in the Syrdarya basin and comprises the North and South Karamurun mines operated by Mining Company #6, with Irkol and (North) Kharasan 1&2.

Kharasan: In 2005 UrAsia Energy Ltd (now Uranium One Inc) of Canada paid US$ 75 million for a 30% share of the Kyzylkum joint venture which owns the (North) Kharasan project. Kharasan 1 in mid-2013 had measured & indicated resources of 8561 tU, and proven and probable resources of 7132 tU. Inferred resources were 17,940 tU. Uranium One projected average cash cost of production for 2014 was $24/lb U_3O_8.

Kharasan 2 is to the south of this and was owned by Kazatomprom but is now controlled by the Baiken-U joint venture, including 95% Japanese equity. Pilot production commenced in 2009.

In April 2007 several Japanese companies – the Energy Asia consortium led by Marubeni – bought 40% of the Kharasan project to directly take 2000 tU/yr when it was in full production at 5000 tU/yr, planned to be about 2014. Project funding was $70 million from the Japan Bank for International Cooperation and $30 million from Citibank. Uranium One retains 30% equity of (north) Kharasan 1 through Kyzylkum JV.

A 2000 tU per year processing facility is matched with a 1000 tU/yr satellite plant. Pilot production commenced in April 2009 with Kharasan 1 to reach 3000 tU/yr by 2014, and Kharasan 2 to reach 2000 tU/yr in 2014. In fact production from both mines together reached only 2500 tU in 2015. Pre-commercial mining commenced in 2008 first significant production for both was early 2010. Production from the $430 million project will primarily supply Japanese utilities. In August 2009 Kazatomprom announced that a wrong technological decision in 2006 regarding development of the deposits had "led to a failure of the 2008-09 production program" and consequent lack of funds, but this was being rectified. Uranium One said that bore holes had been drilled incorrectly and that organic matter was increasing acid consumption.

Irkol started up in 2008, and ramped up for 750 tU/yr by 2010. In October 2008 China's CGN-URC took a 49% share of it through the Semizbai-U JV (see introductory section and below). China Nuclear Energy Industrial Corp (CNEIC) is also involved, possibly as customer for part of the Chinese share of production. The mine was formally opened in April 2009 with some fanfare, as the first mine to be put into commercial operation within the framework of the Kazakhstan-CGNPC nuclear power agreement. All the production is sold to CGN.

Karamurun: North Karamurun was expected to start up in 2007, South Karamurun in 2009.

Southern mining group

The Southern mining group in the same Syrdarya basin has the Zarechnoye mine.

Zarechnoye, discovered in 1977, started production early in 2009. Reserves were earlier quoted at 19,000 tU, but in mid-2013 measured & indicated resources are 7988 tU and proven and probable resources 4510 tU. Inferred resources are 4500 tU. The US$ 60 million Zarechnoye joint venture involved Kazatomprom (49.67%), ARMZ (49.67% – to provide finance) and Kyrgyzstan's Kara Baltinski Mining Combine (0.66%), which finally treats and calcines the product there, 400 km east. The mine produces over 930 tU/yr. In mid-2010 ARMZ agreed to transfer its share to Uranium One. Uranium One projected average cash cost of production for 2014 as $28/lb U_3O_8.

South Zarechnoye was discovered in 1989 and was being developed by the same joint venture to commence production in 2014, eventually at 620 tU/yr. However, the project was put on hold in 202 due to low uranium price and a reduced resource estimate. In November 2013 Uranium One reported that “mineral resources on this property are insufficient to support development”.

In June 2006 Tenex signed a US$ 1 billion uranium supply contract with Zarechnoye JV for up to 6000 tU per year from 2007 to 2022. Initially this will come from Zarechnoye mine, but Budenovskoye will also contribute.

Northern Kazakhstan province

Outside of these two basins, in the Northern Kazakhstan province, the Vostok underground mine continues in production, with Zvezdnoye. The **Semyibai** ISL mine was commissioned at the end of 2009 with a capacity of 500 tU/yr from a uranium-rare earths deposit, and the second stage 200 tU/yr came on line in 2011. In 2008 China's CGN-URC took a 49% share of it and in 2015 this equity passed to CGN Mining Co Ltd. It is managed, with Irkol, by Semizbai-U LLP, a joint venture. China Nuclear Energy Industrial Corp (CNEIC) is also involved, possibly as customer for part of the Chinese share of production.

Earlier, Itochu Corp of Japan has signed a uranium purchase agreement with KazAtomProm for some 3000 tonnes of uranium over 10 years to be marketed in Japan and the USA. KazAtomProm intends to use a US$60 million loan from Japan¹s Mizuho Corporate Bank to raise uranium production at the Central Mynkuduk deposit to 1000 tU/yr, of which Itochu Corp will receive 300t.

Kazkh Uranium Resources (old data) **6 Provinces**

province	resources: tonnes U	proportion of Kazakh
Chu-Sarysu		60.5%
Northern (Stepnoye) group	750,000	
Eastern (Tsentralnoye) group	140,000	

province	resources: tonnes U	proportion of Kazakh
Syrdarya		12.4%
Western (#6) group	180,000	
Southern (Zarechnoye) group	70,000	
Northern	256,000	16.5%
Ily	96,000	6%
Prikaspyi/ **Caspian**	24,000	1.8%
Balkhash	6,000	0.4%

The Chu-Sarysu and Syrdarya deposits are all suitable for ISL recovery, the Northern deposits are mostly in hard rock apart form some ISL at Semizbai, Ily mineralisation is in coal deposits, Caspian has phosphate deposits, and Balkhash has some hard rock volcanic mineralisation but the major deposits were exhausted in the Soviet era. A 2014 estimate puts 77% as amenable for ISL.

All uranium is exported, and with the 2006 joint venture agreements, Russia is the main immediate customer, but China now receives more than half of production.

Health and environment

Kazatomprom said that its enterprises in 2014 continued to ensure ecological safety at its mines, and 23 of the company's affiliates and subsidiaries have ecological management standards certification. More than KZT 1.19 billon ($11 million) was spent in 2014 on measures to reduce the environmental impact of uranium mining, including efficiency improvements to dust and gas collecting installations and water purification units.

Occupational safety and security at uranium production sites is monitored and in 2014 the number of detected violations of occupational and industrial safety requirements dropped by 28% compared with 2013.

Fuel cycle: front end

The internationally-significant **Ulba Metallurgical Plant** (UMP) at Oskomen also known as Ust Kamenogorsk in the east of the country was commissioned in 1949. It has a variety of functions relevant to uranium. (It also produces beryllium, niobium and tanatalum.)

In June 2008 the formation of a new company – **Ulba Conversion** LLP – was announced, to build a 12,000 t/yr uranium hexafluoride conversion plant here, with Cameco providing the technology and holding 49% of the project. Ulba has produced HF since 1952, and the new conversion subsidiary would fit in with Russian JV enrichment arrangements. In May 2013 Cameco said that it expected construction of the plant with 6000 t/yr capacity to commence in 2018, with first production in 2020, subject to a feasibility study from 2014. This plant will produce UO_3 for conversion to UF_6 at Port Hope in Canada.

Kazatomprom has a JV with Russia's TVEL for **uranium enrichment**, (agreed with Tenex in 2006 and set up in 2008). Initially this envisaged adding to the enrichment plant at Angarsk in southern Siberia where Russia has its main conversion plant and a small enrichment plant now being expanded to 4.2 million SWU/yr. Kazatomprom and Tenex agreed to finance a 5 million SWU/yr increment to this. Each party would contribute about US$ 1.6 billion and Kazatomprom would hold 50% equity. When this looked uneconomic due to surplus enrichment capacity, in March 2011 Russian equity in the JV was transferred from Tenex to TVEL and the Kazatomprom-TVEL JV Uranium Enrichment Centre (Closed Joint Stock Company UEC) was offered a share in the Urals Electrochemical Combine (Open Joint Stock Company UECC) which has a 10 million SWU/yr plant at Novouralsk instead. The Kazakh share in UEC would be 50%, related to the need to enrich 6000 tU/yr, and estimated to cost up to $500 million (though amount not disclosed). In the event the joint venture CJSC UEC took up a 25% share of UECC in September 2013 and became entitled to half its output – 5 million SWU/yr. In 2014 the UEC CJSC share was 4.99 million SWU, and in 2015 it was 5.11 million SWU. This is distinct from the International Uranium Enrichment Centre (IUEC).

In September 2007 the joint stock company Angarsk International Uranium Enrichment Centre (**IUEC**) was registered with 10% Kazatomprom ownership and the balance Techsnabexport (Tenex). This share is being sold down to other partners – Ukraine confirmed 10% share in 2008, and Tenex is to hold only 51% eventually.

WORLD NUCLEAR ASSOCIATION

Uranium in Uzbekistan

(Updated May 2017)

- **Uzbekistan has considerable mineral deposits, including uranium.**
- **It is the world's seventh-ranking uranium supplier, and is expanding production.**
- **Japanese and Chinese joint ventures are active in uranium development, especially focused on black shales.**

Uzbekistan was a significant source of Russian uranium supply until independence in 1991. Uranium production until then took place in Uzbekistan, Kyrgyzstan and Tajikistan, with little regard for national borders and much of the treatment being in Tajikistan. Today, most uranium is mined in the middle of the country, with Navoi as the centre, linked to mines by railway.

The country's total electricity generation in 2014 was 55 TWh, with 41 TWh from gas, 2 TWh from coal and 12 TWh from hydro.

According to the 2016 *Red Book*, Uzbekistan has 97,560 tU in Reasonably Assured Resources plus Inferred Resources, to US$ 130/kg U in sandstones, plus 32,900 tU in black shales. The latter have so far not supported commercial production, and foreign expertise is being sought for them. In February 2014 Goskomgeo (State Committee for Geology and Mineral Resources) reported resources of 138,800 tU in sandstones and 47,000 tU in black shales.

Navoi Mining & Metallurgical Combinat (NMMC) is part of the Uzbekistani state holding company Kyzylkumredmetzoloto, and undertakes all uranium mining in the country, as well as gold mining and other activities. Until 1992, all uranium mined and milled in Uzbekistan was shipped to Russia. Since 1992, practically all Uzbekistani uranium production has been exported to the USA and other countries through Nukem Inc. A total of 128,700 tU had been produced to the end of 2011. In 2015 production was 2385 tU.

In 2008 South Korea's Kepco signed agreements to purchase 2600 tU over six years to 2015, for about US$ 400 million. In May 2014 China's CGN agreed to buy $800 million of uranium through to 2021, and China customs was reported as saying that Uzbekistan was second only to Kazakhstan as a uranium supplier to the country. In 2013, 1663 tU was supplied to China.

During the Soviet era, Uzbekistan provided much of the uranium to the Soviet military-industrial complex, with anniual production peaking at 3800 tU in mid 1980s. Five "company towns" were constructed to support uranium production activities: Uchkuduk, Zarafshan, Zafarabad, Nurabad, and Navoi, with a combined population of some 500,000. They remain centres of five mining districts. Uranium industry employment in 2005 was put at about 7000, though some 65,000 were employed by NMMC overall in 2012.

NMMC commenced operation focused on uranium and gold in 1958 in the desert region of Central Kyzylkum province, particularly the Uchkuduk deposit (mined underground and open pit from 1964), which led to the discovery of subsequent deposits of similar kind. In 1966, underground mining began at the Sabyrsay deposit in Samarkand and in 1977 at the Sugraly deposit near Zarafshan. In 1978, ISL was initiated at the Ketmenchi deposit. In 1975 the Sabyrsay deposit was being mined by ISL. Underground mining continued to 1990 and open pit to 1994, but mines are all now in situ leach (ISL). Uranium-bearing solutions are sent by rail to the central hydrometallurgical HMP-1 plant in Navoi for final recovery of U_3O_8 product. This plant was commissioned in 1964 and developed through to 1983. Bacterial leaching was introduced in 2011.

NMMC has produced more than 2000 tU per year since 2004, and over 2009 to 2015 production was about 2400 tU/yr. Completion of Alendy, Aulbek and North Kanimekh mines in 2013 was expected to increase uranium production significantly as they ramped up to full capacity in 2016.

In April 2015 NMMC announced plans approved by the government to implement 27 projects to modernize its production facilities by 2019, at a total cost of $985 million. Among the projects are the construction of a mining and distribution complex in Samarkand region, the development of the main raw material base – the Muruntau mine, and the modernization and technical re-equipment of other production facilities. NMMC's four metallurgical plants in Navoi, Zarafshan, Uchkuduk and Zarmitan were mentioned. It also planned to complete the construction of three uranium mines in the Central Kyzylkum Desert, at a cost of US$75 million.

In 2013 exports to China doubled to 1663 tU.

A uranium production development program is being implemented for the period of 2014-2020, and then extending to 2030. This has involved mining of the Kendyk-tyube, Lyavlyakan, Tokhumbet, Aksay, Sugrali, Nurbulok, Alendy, Aulbek deposits being commenced; the North Kanimekh mine being ramped up to its designed production capacity; and handling high carbonate levels at the Maylisay deposit being resolved. It was expected that 2016 uranium production would increase from 2,400 tonnes to 4,200 tonnes.

Uzbek uranium production (tonnes U)

Division	2015	2016
Northern (Uchkuduk)		731
Central (Zarafshan)		0
Number 5 (Zafarabad)		1039
Southern (Nurabad)		635
Total	**2385**	**2405**

NMMC has several divisions, the Northern and Central ones plus part of #5 are in the Kyzylkum Desert region of Navoi province.

NMMC divisions

Northern mining directorate

Centred on **Uchkuduk**, the Northern mining district 300 km north of Navoi was established to mine uranium at Uchkuduk, from 1961, by underground and open pit mines, with ore treated at the central plant in Navoi. Since 1965 ISL uranium mining has been used at Uchkuduk and since 1995, at Kendyk-Tyube. There is also a 450,000 t/yr sulfuric acid plant at Uchkuduk (possibly in conjunction with a copper smelter). Resources are 51,000 tU, and annual production 700-750 tU.

Central mining directorate

In the **Zarafshan** or eastern mining district, about 200 km north of Navoi, Sugraly was mined underground from 1977 and then ISL to 1994, when it was closed. NMMC had a joint venture with Areva to redevelop the **Sugraly** deposit with reported 38,000 tU resources, but this appears to have lapsed. Sugraly is a thick deposit with complex mining and geological conditions and high carbonate content. Resources are 50,000 tU, with no current production. An integrated processing facility at Sugraly was put into operation in 2014.

Mining directorate #5

The mining district #5 mostly in Bukhara province, west of Navoi and headquartered in **Zafarabad**, close to Navoi was set up in 1971 by another entity in Bukhara province and became part of NMMC in 1993. It mines the Bukinay group of uranium deposits by ISL methods. Mines include North & South Bukinay (from 1970), Beshkak (from 1978), Istiklol, Kukhnur, Lyavlyakan (from 1998), Tokhumbet (from 2004) and South Sugraly. District resources are 52,000 tU, and annual production 1000-1200 tU and rising to 2100 tU

Southern mining directorate

The Southern mining district in Samarkand province, southeast of Navoi, and headquartered at **Nurabad**, was founded in 1964 to mine the Sabirsay uranium deposit by underground methods, which continued to 1983. ISL then took over, and continues to be the main mining method. The operation was transferred from Tajikistan to NMMC about 1994*. Other mines are Ketmenchi (ISL since 1978), Jaarkuduk, Yogdu, Shark and Ulus. Resources are 13,000 tU, and annual production is 600-650 tU.

* In Soviet times, to 1992, the Leninabad Mining and Chemical Combine located at Chkalovsk, a few kilometres southeast of Khujand (Khodjend/ Khodzhent), Sughd province, northeren Tajikistan, on the Syr Darya River in the western part of the Ferghana Valley, is to the east of Uzbek's Samarkand province. The Combine incorporated seven mines and several plants, notably Combine No. 6 (Uranium Plant V), and it processed up to 1,000,000 tonnes of uranium ore per year to produce yellowcake for the Soviet nuclear power and defence industries. A lot of this was at the central plant. Reportedly, Chkalovsk once had the capability to convert uranium concentrate into uranium hexafluoride. It was established in 1945 as a large-scale hydrometallurgical uranium enterprise, based on the uranium deposits of Tajikistan, Kyrgyzstan and Uzbekistan. Uranium mining ceased in Tajikistan in 1992, and the Combine became the industrial association Vostochnyy Eastern Combine for Rare Metals (IA Vostokredmet) which is a significant industrial complex specialising today in underground and heap leaching of metals. There are considerable amounts of uranium tailings and disturbed areas from the combine's operation – over 100 square kilometres overall in Tajikistan, according to a Russian estimate in a 2002 IAEA report. See Appendix.

Mining directorate #2

In MA#2 at Krasnogorsk, Parkent region, Tashkent province in the east of the country, the Chauly uranium deposit was previously mined, but the focus there is on phosphorite now. It became part of NMMC in 1995.

New mines: Northern, Central and #5

NMMC has started mining the major new **Northern Kanimekh** deposit, northwest of Navoi, costing US$ 34 million. Northern Kanimekh ore occurs 260 to 600 metres deep with 77% of uranium reserves present at 400-500-metre depth. This requires a special approach to building wells and uranium mining process. The pilot plants at Northern Kanimekh and Alendy (Directorate #5) were commissioned in 2008-09 and the two commercial mines were completed at the end of 2013, and were expected to achieve full capacity in 2015.

NMMC also built a pilot plant for ISL at Yarkuduk and Tokhumbet deposits. It has started operation of the US$ 21 million Aulbek ISL mine near Lyavlyakan in central Kyzylkum (Directorate #5), which ramped up to 2013, and also Meylisay and Tutlinskaya ploshchad, costing about US$30 million.

Over 2008-12 NMMC invested US$ 230 million in upgrades to expand the existing mining and processing capacities, renew the fleet of process equipment, and establish up to seven new mines. "As part of an increase in uranium production up to 2012, the expansion and reconstruction of sulfuric acid production, at a cost of about $12 million, will be carried out. Implementation of the program will make it possible to increase uranium production in 2012 by 50%". Early in 2009 the Uzbek president said that the world economic crisis would slow all this development, though full commissioning of the Aulbek, Alendy and North Kanimekh mines in Central Kyzylkum at the end of 2013 would enable a 40% increase of NMMC production.

In August 2013 NMMC suspended construction of Meylisay and Northern Maizak mines in central Kyzylkum due to high carbonate content in the ore rendering ISL inefficient. However Navoi said that in 2015 the technology of uranium mining would be optimized at Meylisay deposit. Aulbek and North Kanimekh also have high carbonate levels.

International ventures, black shales

China: In August 2009 Goscomgeo and China Guangdong Nuclear Uranium Corp. (CGN-URC) set up a 50-50 uranium exploration joint venture, Uz-China Uran, to focus on the black shale deposits in the Boztau-skaya area in the central Kyzylkum desert of the Navoi region. Some 5500 tU resources are reported. Over 2011-13 CGN-URC was to develop technology for the separate production of uranium and vanadium from these black shale deposits with a view to commencing production from them.

Russia: In January 2006 Techsnabexport (ARMZ subsidiary) signed a memorandum of understanding with NMMC and Goskomgeo (State Committee for Geology and Mineral Resources of Uzbekistan) to set up a uranium mining joint venture based on the Aktau deposit. Initially, it was planned that the joint venture would start operations late 2006, but after four years' negotiation no agreement could be reached and Russia withdrew in mid 2010. Aktau's probable resources are estimated 4,400 tons of uranium accessible by ISL and with treatment of 300 tU/yr production envisaged at Navoi. However, the ore is complex and this has apparently deterred establishment of the project. Goskomgeo invited ARMZ to consider its black shales, but ARMZ declined on the basis that no treatment process was known for them.

In 2007 Russia offered to enrich Uzbekistan uranium in the International Uranium Enrichment Center in Angarsk.

Japan: In September 2006 a Japan-Uzbek intergovernmental agreement was aimed at financing Uzbek uranium development and in October2007 Itochu Corporation agreed with NMMC to develop technology to mine and mill the black shales, particularly the Rudnoye deposit, and to take about 300 tU/yr from 2007. A 50-50 joint venture was envisaged, but no more was heard until February 2011 when Itochu signed a 10-year "large-scale" uranium purchase agreement with NMMC.

In mid-2008 Mitsui & Co. signed a basic agreement with the Uzbek government's Goscomgeo (State Geology and Mineral Resources Committee) to establish a joint venture for geological investigations regarding the development of black-shale uranium resources at the Zapadno-Kokpatasskaya mine, 300 km NW of Navoi.

In mid-2009, and further to an April 2007 MOU, Goscomgeo and the Japan Oil, Gas and Metals National Corporation (JOGMEC) signed an agreement for uranium and rare earths exploration in the Navoi region, focused on ISL-type sandstone deposits and black shales, with a view to a Japanese company taking a 50% interest in any resources identified and developing them. In February 2011 a further broad agreement was signed between the two. In August 2013 JOGMEC was granted a licence to explore for uranium in two sandstone deposits, Juzkuduk and Tamdiykuduk-Tulyantash, for five years with rights to mine, following a July agreement with NMMC.

Organisation

The Uzbekistani State Committee for Safety in Industry and Mining (Gosgortekhnadzor) supervises ministries engaged in mining.

The Nuclear Regulations Inspectorate under Gosgortekhnadzor has responsibility for the control and supervision of the research reactors and all nuclear and radioactive materials (including spent fuel) in Uzbekistan.

Research & development

There have been two research reactors, a 10 MW tank type – WWR-SM – operating since 1959 at the Institute of Nuclear Physics, Uzbek Academy of Sciences in Tashkent, and a small 20 kW one operated by JSC Foton in Tashkent. This had been converted to run on low-enriched uranium from TVEL, and all HEU fuel was returned to

Russia. Decommissioning the Foton reactor is being undertaken over 2015-17. The larger WWR-SM shut down in July 2016, with decommissioning intended to begin soon after. However, in February 2017 it was decided to refurbish it, and restart it in July 2017.

The state enterprise Scientific Production Centre Urangeologiya undertakes uranium exploration in new areas.

Legacy sites

See section in information papers on Tajikistan and Kyrgyzstan.

In June 2015 the European Bank for Reconstruction and Development (EBRD) set up a fund to deal with radioactive contaminated material resulting from Soviet-era uranium mining and processing in the Kyrgyz Republic, Tajikistan and Uzbekistan. It drew attention to legacy sites along the tributaries to the Syr Darya River, running through the Fergana Valley, which is shared by the Kyrgyz Republic, Tajikistan and Uzbekistan.

Non-proliferation

Uzbekistan is a party to the NPT and in 1998 ratified an Additional Protocol agreement with the IAEA. It has also ratified the Central Asia Nuclear Weapon Free Zone treaty, with Kyrgyzstan and Tajikistan.

Main References

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WORLD NUCLEAR ASSOCIATION

China's Nuclear Fuel Cycle

(Updated September 2017)

- **China has become self-sufficient in most aspects of the fuel cycle.**
- **China aims to produce one-third of its uranium domestically, obtain one-third through foreign equity in mines and joint ventures overseas, and to purchase one-third on the open market.**
- **China's two major enrichment plants were built under agreements with Russia but much current capacity is indigenous.**
- **China's R&D in nuclear technologies is second to none in the world, particularly in high-temperature gas-cooled and molten salt-cooled reactors.**

China has stated it intends to become self-sufficient not just in nuclear power plant capacity, but also in the production of fuel for those plants. However, the country still relies to some extent on foreign suppliers for all stages of the fuel cycle, from uranium mining through fabrication and reprocessing, but mostly for uranium supply. As China rapidly increases the number of new reactors, it has also initiated a number of domestic projects, often in cooperation with foreign suppliers, to meet its nuclear fuel needs.

The national policy is to obtain about one-third of uranium supply domestically, one-third from Chinese equity in foreign mines, and one-third on the open market. Increasingly, other stages of the fuel cycle will be indigenous. Uranium demand in 2020 is expected to be over 11,000 tU (with 58 reactors operating), in 2025 about 18,500 tU (for 100 reactors) and in 2030 about 24,000 tU (for 130 reactors). UxC reports that China imported over 115,000 tU over 2009-14, notably 25,000 tU in 2014 and 10,400 tU to July in 2015. With annual consumption currently about 8000 tU, much of this will be stockpiled.

China National Nuclear Corporation (CNNC) maintains a strong monopoly on the nuclear fuel cycle in China, notably the front end, forcing China General Nuclear Power (CGN) to work around this, principally with international ventures, some involving large capital outlays. With the merger of SNPTC and CPI to form SPI in 2015, so that SNPTC took over all the nuclear-related business of CPI to function as an active subsidiary of SPI, SNPTC said it intended to get into both uranium mining and fuel fabrication.

CNNC is also the main operator in the fuel cycle back end, evidenced by a series of agreements with Areva for a reprocessing plant. That in November 2015 was part of a wider agreement in relation to all aspects of the fuel cycle, and foreshadowing an intention to take equity in Areva NC (now Areva NewCo), in connection with evolving agreements to build a reprocessing plant based on Areva technology.

Following Areva's restructuring, a new framework agreement between Areva New Co and CNNC was signed in February 2017, covering "the whole industrial chain of the nuclear fuel cycle". In particular it supports plans for construction of a reprocessing plant in China.

As well as a long-standing close relationship with France, China has a bilateral nuclear cooperation agreement ('123 agreement') with the USA from 1985 which was renewed in 2015. This is a prerequisite for nuclear trade in plant and materials that involves the USA.

Domestic uranium resources and mining

CNNC is the only current supplier of domestic uranium. CGN has responded energetically to this situation through its subsidiary China Guangdong Nuclear Uranium Resources Co Ltd (CGN-URC) as described below.

China now claims to be “a uranium-rich country” on the basis of some two million tonnes of uranium, though published known in situ uranium resources were 366,000 tU to $130/kg at 1/1/15, of which 173,000 tU were reasonably assured, and in situ inferred resources were 193,000 tU in the 2016 edition of the 'Red Book', which are modest in relation to the country's needs. New discoveries in the north and northwest in sandstones, and deep hydrothermal ones in southeast China have raised expectations. There is also potential in lignite, black shale and phosphates. Over 2013-14 about 71,000 tU was added to known resources in northern China – in the Yili, Erlian, Erdos, Songliao and Bayingebi basins as well as Longshoushan – and 29,000 tU in southern China in the Rouoergai and Dazhou uranium fields. The 2016 Red Book tabulates 366,000 tU in 21 deposits in 13 provinces, 39% of the total in Inner Mongolia, 21% in Jiangxi, 14% in Xinjiang and 12% in Guangdong.

As of 2012, 35% of resources were in sandstone deposits mainly in the north and northwest, 28% in vein/granite deposits in central and southeast China, 21% in volcanic deposits in the southeast, and 10% in black shale in the southeast. Most known resources are at less than 500m depth.

Domestic production was 1616 tU/yr in 2015, enough for about 7000 MWe, apart from new cores. This was approximately 530 t from sandstone by ISL, 620 t from granite-related ore and 450 t from volcanic-related ore. All production is acid-leached. By international standards, China's ores are low-grade and production has been inefficient. The nuclear power companies are not depending on the national goal of sourcing one-third of uranium domestically, and are ramping up international arrangements to obtain fuel.

Operating uranium mines in China

Mine[a]	Province	Type	Nominal capacity tonnes U/yr (planned)	Started
Yining	Xinjiang	In-situ leach (ISL)	480 (800)	1993
Lantian	Shaanxi	Underground, heap leach	100	1993
Benxi	Liaoning	Underground, block leach	120	1996
Qinglong	Liaoning	Underground, heap leach	100 (200)	2007
Fuzhou	Jiangxi	Underground, mill	350 (500)	1966
Chongyi	Jiangxi	Underground, heap leach	200 (300)	1979
Shaoguan	Guangdong	Underground, heap leach	200 (300)	2008
Total			**1550 (2320)**	

Xinjiang's Yili basin in the far west of China, in which the Yining (or Kujiltai) ISL mine sits, is contiguous with the Ili uranium province in Kazakhstan, though the geology is apparently different. The Fuzhou mine in the southeastern Jiangxi province is in a volcanic hydrothermal deposit, as is Qinglong in Liaoning. The other mines are in granitic deposits. Source: Red Book 2016.

China Nuclear Uranium Corporation, a subsidiary of CNNC, operates these mines. Pilot testing is under way on the Shihongtan deposit in the Turpan-Hami basin of Xinjiang, and the western portion appears suitable for ISL. A uranium-molybdenum mine is being developed at Guyuan, Hebei province, in granites. Other uranium deposits with abundant reserves but with complex mining and milling technologies are the subject of pilot tests and feasibility studies, such as the Dongsheng and Erlian sandstone deposits in Inner Mongolia. The former, in the Ordos/Erdos Basin, has an estimated 30,000 tonnes of uranium in a palaeochannel system, the latter is unsuitable for ISL due to low permeability.

An underground uranium mine at Hengyang in Hunan is on stand-by. The mine, which started up in 1963, has a nominal production capacity of 500-1000 tU/yr.

CGN subsidiary China Guangdong Nuclear Uranium Resources Co Ltd (CGN-URC) was set up in 2006 to be responsible for CGN's fuel supply, and in particular to undertake uranium exploration and mining, uranium trade, and management of fuel processing for CGN. It is pursuing the second stage of a planned three-stage development, with diversification of supplies and integration of front-end services. A third stage will involve new

technology as well as consolidation of its role as viable supplier. It aims to free up international trade and bring about better logistics. Early in 2012 CGN-URC changed its name to CGNPC-Nuclear Fuel Co Ltd (CGNPC-NFC) to reflect its wider interest in all front-end fuel cycle aspects, but this name change did not persist.

CGN-URC has been undertaking uranium exploration in Xinjiang Uygur autonomous region, and also in Guangdong, via CGN-URC Guangdong Uranium Ltd. In May 2011 CGN-URC announced that it was developing two 500 tU/yr mines on these deposits, to operate from 2013, but this venture appears to have stalled.

Mineral exploration

CNNC's Geological Survey Bureau and the Beijing Research Institute of Uranium Geology are the key organisations involved with a massive increase in exploration effort since 2000, focused on sandstone deposits amenable to ISL in the Xinjiang and Inner Mongolia regions, and the granite and volcanic metallogenic belts in southern China, including the Xiangshen uranium orefield.

In northern China, the exploration is focused on previously discovered mineralisation spanning the Yili, Turpan-Hami, Junggar and Tarim basins of Xinjiang Autonomous Region, and the Erdos/Ordos, Erlian, Songliao, Badanjili and Bayingebi basins of Inner Mongolia. The Ordos basin itself covers over 250,000 sq. km of Shaanxui, Shanxi, Gansu and Inner Mongolia and contains major coal units as well as commercial gas reservoirs and some oil. It starts just north on Xi'an in Shaanxi province and extends nearly to Baotou near the Mongolian border. By 2012 this had become the premier uranium region of China, right across its north. In 2008 significant deposits were discovered in the Yili basin of Xinjiang, including J3, and then in the Ordos basin Nalinggou, Darong and (in 2012) Daying were discovered. Daying is expected to become China's largest uranium resource and in late 2014 was being described by the Geological Survey Bureau as 'world class'. Also in the Erlian basin the Bayanwula deposit, a roll front deposit with biogenic origins, was identified. In the Songliao basin in the east of Inner Mongolia the Qianjiadian deposit was identified, and in 2017 CNNC announced "a breakthrough in sandstone-type uranium ore exploration," and expects a new orebody – with an overall length of more than 10 km – to develop into a large uranium deposit.

CNNC Inner Mongolia Mining Industry LLC based in Baotou is responsible for overseeing natural uranium geological prospecting, scientific research and project management in the middle and western parts of Inner Mongolia. Its Mining Business Division is focused mainly evaluating the Nalinggou and Bayanwula projects by the end of 2015. The Division is also setting up regional headquarters in Inner Mongolia, Jiangxi, Guangdong and Xinjiang.

Some northern uranium mineralization is interbedded with coal deposits, giving rise to concerns about mining efficiently, and about the amount of radioactivity in coal as burned in some northern power stations. The Daying uranium deposit in Inner Mongolia is evidently in this category, with separate layers of coal and uranium ore in sandstone palaeochannels extending over many kilometres. The coal resource is major.

In March 2013 CNNC signed an agreement with China Petroleum & Chemical Corp. (SINOPEC) to set up the joint venture of CNNC and SINOPEC Uranium Resources Co. Ltd to accelerate the exploration for uranium resources, starting with the Chaideng area of Inner Mongolia. The Chaideng prospecting region of Dongsheng Coal Field is in the northeast of the Ordos Basin.

In August 2014 CNNC signed an agreement with Shenhua Group to recover uranium from a mine near Ordos city. In March 2016 it signed a broader strategic agreement. Shenhua is the largest coal mining company in China.

The Dongsheng group of uranium deposits is located in south-central Inner Mongolia, about 100 km south of Baotou and on the northern edge of the Ordos Basin. Uranium ore bodies are mostly in area of 200 sq. km hosted by fluvial sandstones in the Zhiluo Formation as a regional redox front, and to a lesser degree within the Yan'an Formation, which has coal-bearing strata. Individual tabular and roll-front ore bodies are several tens to one hundred metres long, up to 20 m thick, and have average ore grades of 0.02 to 0.05%U. They plunge from 75 to 185 m deep, following the dip of the Zhiluo formation.

Russia's Nuclear Fuel Cycle

(Updated October 2017)

- **A significant increase in uranium mine production is planned.**
- **There is increasing international involvement in parts of Russia's fuel cycle.**
- **A major Russian political and economic objective is to increase exports, particularly for front-end fuel cycle services through Tenex, as well as nuclear power plants.**

Russia uses about 3800 tonnes of natural uranium per year. After enrichment, this becomes 190 tU enriched to 4.3% for 9 VVER-1000 reactors (at 2004, now 13), 60 tU enriched to 3.6% for 6 VVER-440s, 350 tU enriched to 2.0% for 11 RBMK units, and 6 tU enriched to 20% (with 9 tU depleted) for the BN-600. Some 90 tU recycled supplements the RBMK supply at about 2% enrichment. This RepU arises from reprocessing the used fuel from BN, VVER-440 and marine and research reactors.

There is high-level concern about the development of new uranium deposits, and a Federal Council meeting in April 2015 agreed to continue the federal financing of exploration and estimation works in Vitimsky Uranium Region in Buryatia. It also agreed to financing construction of the engineering infrastructure of Mine No. 6 of Priargunsky Industrial Mining and Chemical Union (PIMCU). The following month the Council approved key support measures including the introduction of a zero rate for mining tax and property tax; simplification of the system of granting subsoil use rights; inclusion of the *Economic Development of the Far East and Trans-Baikal up to 2018* policy in the Federal Target Program; and the development of infrastructure in Krasnokamensk.

In June 2015 Rosgeologia signed a number of agreements to expedite mineral exploration in Russia, including one with Rosatom. It was established in July 2011 by presidential decree and consists of 38 enterprises located in 30 regions across Russia, but uranium is a minor part of its interests.

Uranium resources and mining

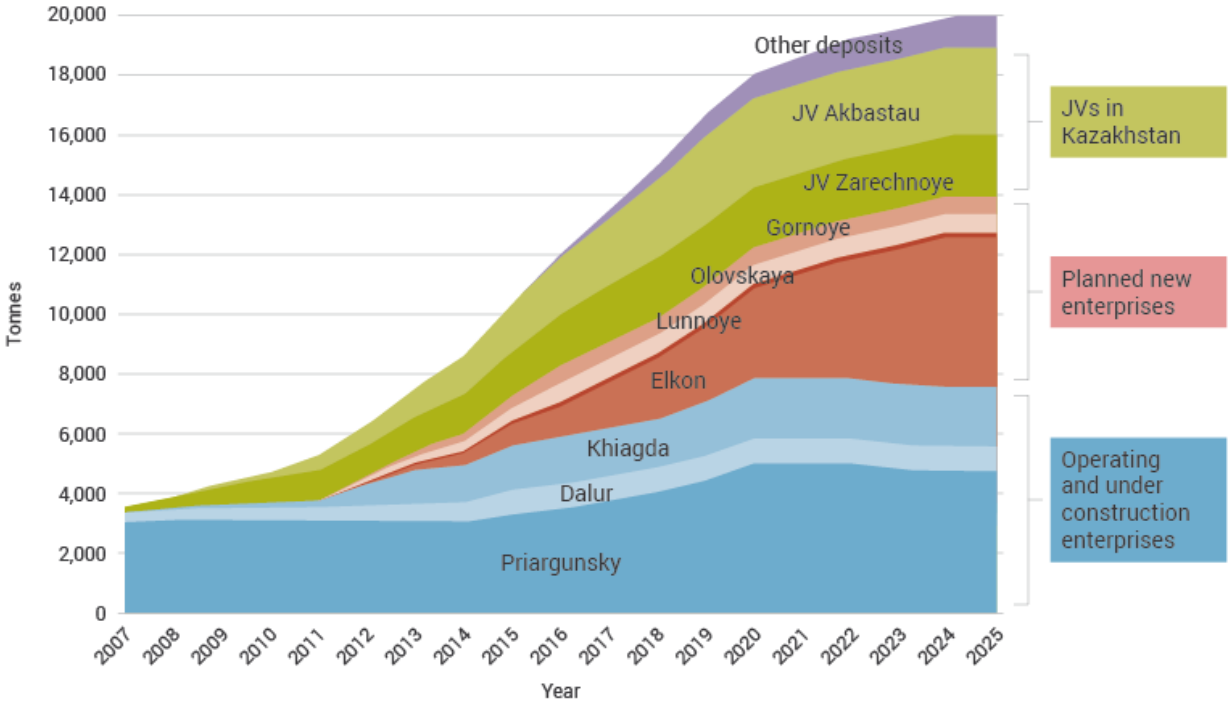
Russia has substantial economic resources of uranium, with about 9% of world reasonably assured resources plus inferred resources up to US$ 130/kg – 505,900 tonnes U (2014 *Red Book*). Rosatom reported ARMZ resources as 517,000 tU in September 2015, mostly requiring underground mining. Historic uranium exploration expenditure is reported to have been about $4 billion. The Federal Natural Resources Management Agency (Rosnedra) reported that Russian uranium reserves grew by 15% in 2009, particularly through exploration in the Urals and Kalmykia Republic, north of the Caspian Sea.

Uranium production has varied from 2870 to 3560 tU/yr since 2004, and in recent years has been supplemented by that from Uranium One Kazakh operations, giving 7629 tU in 2012. In 2006 there were three mining projects in Russia, since then others have been under construction and more projected, as described below. Cost of production in remote areas such as Elkon is said to be US$ 60-90/kg. Spending on new ARMZ domestic projects in 2013 was RUR 253.5 million, though in November 2013 all Rosatom investment in mining expansion was put on hold due to low uranium prices.

Plans announced in 2006 for 28,600 t/yr U_3O_8 output by 2020, 18,000t of this from Russia* and the balance from Kazakhstan, Ukraine, Uzbekistan and Mongolia have since taken shape, though difficulties in starting new Siberian mines makes the 18,000 t target unlikely. Three uranium mining joint ventures were established in Kazakhstan with the intention of providing 6000 tU/yr for Russia from 2007: JV Karatau, JV Zarechnoye and JV Akbastau. (see below and Kazakhstan paper)

* See details for April 2008 ARMZ plans. In 2007 TVEL applied for the Istochnoye, Kolichkanskoye, Dybrynskoye, Namarusskoye and Koretkondinskoye deposits with 30,000 tU in proved and probable reserves close to the Khiagda mine in Buryatia.
From foreign projects: Zarechnoye 1000 t, Southern Zarechnoye 1000 t, Akbastau 3000 t (all in Kazakhstan); Aktau (Uzbekistan) 500 t, Novo-Konstantinovskoye (Ukraine) 2500 t. In addition Russia would like to participate in development of Erdes deposit in Mongolia (500t) as well as in Northern Kazakhstan deposits Semizbai (Akmolonsk Region) and Kosachinoye.

ARMZ Uranium Production Plans 2007



Source: World Nuclear Association

*(this chart is now slightly out of date but still gives a general picture)

AtomRedMetZoloto (ARMZ) is the state-owned company which took over Tenex and TVEL uranium exploration and mining assets in 2007-08, as a subsidiary of Atomenergoprom (79.5% owned). It inherited 19 projects with a total uranium resource of about 400,000 tonnes, of which 340,000 tonnes are in Elkonskiy uranium region and 60,000 tonnes in Streltsovskiy and Vitimskiy regions. The rights to all these resources had been transferred from Rosnedra, the Federal Agency for Subsoil Use under the Ministry of Natural Resources and Environment.

JSC ARMZ Uranium Holding Company (as it is now known) became the mining division of Rosatom in 2008, responsible for all Russian uranium mine assets and also Russian shares in foreign joint ventures. In 2008, 78.6% of JSC Priargunsky, all of JSC Khiagda and 97.85% of JSC Dalur was transferred to ARMZ. In March 2009 the Federal Financial Markets Service of Russia registered RUR 16.4 billion of additional shares in ARMZ placed through a closed subscription to pay for uranium mining assets, on top of a RUR 4 billion issued in mid 2008 to pay for the acquisition of Priargunsky, Khiagda and Dalur. In November 2009 SC Rosatom paid a further RUR 33 billion for ARMZ shares, increasing its equity to 76.1%.

In 2009 and 2010 ARMZ took a 51% share in Canadian-based Uranium One Inc, paying for this with $610 million in cash and by exchange of assets in Kazakhstan: 50% of JVs Akbastau, Karatau and Zarechnoye, mining the Budenovskoye and Zarechnoye deposits. (An independent financial advisor put the value of ARMZ's stakes in the

Akbastau and Zarechnoye JVs at $907.5 million.) Uranium One has substantial production capacity in Kazakhstan, including now those two mines with Karatau, Akdala, South Inkai and Kharasan, as well as small prospects in USA and Australia (sold in 2015). In 2013 ARMZ completed the purchase of outstanding shares in Uranium One Inc, and it became a full subsidiary of ARMZ. JSC Uranium One Group (U1 Group) is from December 2016 a 78.4% owned subsidiary of Atomenergoprom and apparently separate from ARMZ.

Following this, late in 2013 Rosatom established Uranium One Holding NV (U1H) as its global growth platform for all international uranium mining assets belonging to Russia, with headquarters in Amsterdam. It lists assets in Kazakhstan, USA and Tanzania, as well as owning and managing Rosatom's stake in Uranium One Inc. In 2013 it accounted for 5086 tU production at average cash cost of $16/lb U_3O_8, and reported 229,453 tU measured, indicated and inferred resources (attributable share). In 2014 it produced 4857 tU and listed resources of 177,000 tU. The company plans to extend its interests into rare earths. Its 'strategic partner' is JSC NAC Kazatomprom.

ARMZ remains responsible for uranium mining in Russia. At the end of 2013 it was 82.75% owned by Rosatom and 17.25% TVEL. Exploration expenditure has nearly doubled in two years to about US$ 52 million in 2008. In 2013 the government approved an exploration budget of RUR 14 billion ($450 million) through to 2020, principally in the Far East and Northern Siberia. Deposits suitable for ISL mining will be sought in the Transurals, Transbaikal and Kalmykyia. Other work will be in the Urals, Siberian, Far East Federal Districts (Zauralsky, Streltsovsky, Vitimsky and Vostochno-Zabaikalsky, and Elkonsky ore regions).

Rosgeologia, the Russian state-run geological exploration services company set up in 2011, has identified "promising" uranium deposits in the North-West Federal District of Russia following completion of a survey of the Kuol-Panayarvinskaya area on the border of the Murmansk region and the Republic of Karelia. It signed an agreement with Rosatom in 2015 to focus on uranium.

CJSC Rusburmash (RBM) is the exploration subsidiary of ARMZ. VNIPIPT is the subsidiary responsible for R&D and engineering of mining and processing plants.

In December 2010 ARMZ made a $1.16 billion takeover bid for Australia's Mantra Resources Ltd with a prospective Mkuju River project in southern Tanzania, which was expected in production about 2013 at 1400 tU/yr, but is now deferred. This is now under U1H.

Domestic mining

In 2009 the government accepted Rosatom's proposal for ARMZ and Elkonsky Mining and Metallurgical Combine to set up the "open-type joint stock company" EGMK-Project. The state's contribution through Rosatom to the EGMK-Project authorized capital will be RUR 2.657 billion, including RUR 2.391 billion in 2009 and RUR 0.266 billion in 2010. EGMK-Project is being set up to draw up the project and design documentation for Elkonsky Mining and Metallurgical Combine (see below).

The Russian Federation's main uranium deposits are in four districts:

- The Trans-Ural district in the Kurgan region between Chelyabinsk and Omsk, with the Dalur ISL mine.
- Streltsovskiy district in the Transbaikal or Chita region of SE Siberia near the Chinese and Mongolian borders, served by Krasnokamensk and with major underground mines.
- The Vitimsky district in Buryatia about 570 km northwest of Krasnokamensk, with the Khiagda ISL mine.
- The more recently discovered remote Elkon district in the Sakha Republic (Yakutia) some 1200 km north-northeast of the Chita region.

Present production by ARMZ is principally from the Streltsovskiy district, where major uranium deposits were discovered in 1967, leading to large-scale mining, originally with few environmental controls. These are volcanogenic caldera-related deposits. Krasnokamensk is the main town serving the mines.

In 2008 ARMZ said that it intended to triple production to 10,300 tU per year by 2015, with some help from Cameco, Mitsui and local investors. ARMZ planned to invest RUR 203 billion (US$ 6.1billion) in the development of uranium mining in Russia in 2008-2015. It aimed for 20,000 tU per year by 2024. Total cost was projected at RUR 67 billion ($2 billion), mostly at Priargunsky, with RUR 4.8 billion ($144 million) there by end of 2009 including a new $30 million, 500 tonne per day sulfuric acid plant commissioned in 2009, replacing a 1976 acid plant.

Russian uranium mining

Production centre	Region	First production	Orebody	Known resources: tU	Capacity: tU/yr
Priargunsky	Transbaikal/ Chita	1968	volcanic	98,000	3000
Dalur	Trans-ural/ Kurgan	2004	sandstone	11,000	800
Khiagda	Buryatia, Vitimsky	2010	sandstone	32,000	1000
Gornoye	Transbaikal/ Chita	deferred	granite	3200	300
Olovskaya	Transbaikal/ Chita	deferred	volcanic	8210	600
Elkon	Yakutia/ Sakha	(2020)	metasomatite	303,600	5000
Lunnoye	Yakutia/ Sakha	(2016?)	polymetallic	800	100 with gold

Source: 2014 'Red Book' except Olovskaya and Lunnoye.

Russian uranium production, tonnes U

Production centre	2012	2013	2014	2015	2016	2017	2018	2019
Priargunsky	2011	2133	1970	1977	1873			
Dalur	529	562	578	590	591			
Khiagda	332	440	442	488	540	plan 693		plan 1000
Gornoye	-	-	0					
Olovskaya	-	-	0					
Elkon	-	-	0					
Lunnoye	-	-	0					
Total	**2872**	**3135**	**2990**	**3055**	**3004**			

Trans-Ural, Kurgan region

A modest level of production is from **Dalur** in the Trans-Ural Kurgan region. This is a low-cost (US$ 40/kg) acid in situ leach (ISL) operation in sandstones. Uksyanskoye is the town supporting Dalur mine. ARMZ's 2008 plan had production at Dalur by acid ISL increasing from 350 to 800 tU/yr by 2019 (expanding from the Dalmatovskoye field in the Zauralsk uranium district to Khokhlovskoye in the Shumikhinsky district, then Dobrovolnoye in the Zverinogolovsky district). In 2014 JSC Dalur completed further exploration of the Khokhlovskoye deposit and increased its resources from 4700 to 5500 tonnes. Production from it will increase from 50 tU in 2015 to 200 t/yr by 2019. A mill upgrade was started in 2016. More than half of 2016 production was from Ust-Uksyansky part of Dalmatovskoye field.

Dalur 'reserves' in 2013 were quoted by ARMZ at 9,900 tonnes. Rare earths and scandium are potential by-products. In 2016 geological exploration and pilot operations at the Dobrovolnoye deposit were completed, and a permit for development was received in June 2017, allowing construction of the plant. Its reserves are quoted as 7067 tU. After pilot operation to 2020, commercial operation is expected to maintain Dalur production at 700 tU per year about 2025 after Dalmatovskoye and Khokhlovskoye are exhausted.

Transbaikal Chita region, Streltsovskiy district

Here, several underground mines operated by JSC **Priargunsky** Industrial Mining and Chemical Union (PIMCU – 85% ARMZ) supply low-grade ore to a central mill near Krasnokamensk. PIMCU was established in 1968, and produces some other metals than uranium. Since 2008 it has been an ARMZ subsidiary. Historical production from Priargunsky is reported to be 140,000 tU (some from open cut mines) and 2011 known resources (RAR + IR) are quoted as 115,000 tU at 0.159%U. In 2013 'reserves' were quoted by ARMZ at 108,700 tonnes. Production is up to about 3000 tU/yr, about one-tenth of it from heap leaching. In 2015 production was 1977 tU and costs were reduced by 11%, so that it hoped to break even in mid-2016.

The company has six underground mines, most of them operating: Mine #1, Mine #2, Glubokiy Mine, Shakhta 6R, Mine #8 with extraction from Maly Tulukui deposit, and Mine #6 (see below). ARMZ's 2008 plan called for Priargunsky's production to be expanded from 3000 to 5000 tU/yr by 2020.

Mine #1 production rate was increased in 2016. It is on the opposite side of the Oktyabriski settlement from mine #2 and about 2 km from it.

Mine #2 was making a loss in 2013 due to market conditions, so it was closed in order to concentrate on bringing mine #8 to full production. Stoping operations resumed in February 2015, with production target 130 tU for the year, from average grade 0.15%. It is now known as section 2 of mine #8. Some production has been exported to France, Sweden and Spain.

Mine #8 began producing in 2011, towards phase 1 target capacity of 400 t/yr by the end of 2014. The total cost of development is expected to be RUR 4.8 billion (RUR 3.5 billion for phase 1). Production was increased 22% in 2016.

Mine #6 development began in 2009 for stage 1 production from 2015 to reach full capacity in 2019, at a cost of RUR 30 billion ($975 million), but this was put on hold in 2013. In March 2015 ARMZ said it hoped to find co-investors in the project, and federal funds might be forthcoming. Then in June 2015 Rosatom's Investment Committee decided to finance the development to about $500 million over 2016 to 2022. This will access the Argunskoye and Zherlovoye deposits which comprise 35% of the Streltsovskoye reserves of 40,900 tU, with much higher grade (0.3%U) than the rest. Production cost from mine #6 is US$ 90/kgU. Future plans for Priargunsky are focused on development on mine #6 to reach 1800 tU/yr production after about 2022. In August 2016 ARMZ said funding of RUR 27 billion ($410 million) was expected, to enable 2022 commissioning. Rosatom reported that the Mine #6 development project is supervised by the government of Zabaikalsky Krai.

Mine #4. Mining the Tulukuy pit of Mine #4 ceased in 1991 due to low grades, but now low-cost block-type underground leaching is ready to be employed in the pit bottom to recover the remaining 6000 tU. Following this the pit will be filled with low-grade ore for heap leaching.

A re-evaluation of reserves in 2012 suggested that mineable resources apart from Mine #6 amounted to only 32,000 tU. Mine #8 resources were quoted at 12,800 tU in December 2012. In 2014 PIMCU, as part of the Kaldera project, identified four promising areas over 100 sq km in the Streltsovskoye ore field, with resources estimated at 80,000 tU, and they will be explored over 2015-17.

In 2014 PIMCU completed an upgrade of its sulfuric acid plant to take daily production from 400 to 500 tonnes, for use in both the conventional mill and in underground and heap leaching. Also the mill (hydrometallurgical plant) process was improved.

There is a legacy environmental problem at Priargunsky arising from 30 waste rock and low-grade ore dumps as well as tailings. Rehabilitation of waste rock dumps and open pits is proceeding and low-grade ores are being heap leached. Dams and intercepting wells below the tailings dams with hydrogeological monitoring and wastewater treatment is addressing water pollution. Final rehabilitation of the impacted areas will occur after final closure takes place. In 2016 ARMZ announced a new heap leaching initiative for very low-grade ores stockpiled on the surface, to produce 50 to 63 tU/yr.

In 2006 Priargunsky won a tender to develop Argunskoye and Zherlovoye deposits in the Chita region with about 40,000 tU reserves. Dolmatovsk and Khokhlovsk have also been identified as new mines to be developed (location uncertain).

Development of **Olovskoye and Gornoye** deposits* in the Transbaikal region near Priargunsky towards Khiagda would add 900 tU/yr production for RUR 135 billion ($5.7 billion). Measured resources together are 12,200 tU and inferred resources 1600 tU, all at 0.072% average (JORC-compliant). In 2007 newly-formed ARMZ set up two companies to undertake this, and possibly attract some foreign investment:

- **Gornoye** Uranium Mining Company (UDK Gornoye) to develop the Gornoye and Berezovoye mines in the Krasnochikoysky and Uletovsky districts in Chita, with underground mining and some heap leach (ore grade 0.226%U) originally to produce 300 tU/yr from 2014, but now anticipating up to 1000 tU/yr from 2025.
- **Olovskaya** Mining & Chemical Company to develop the Olovskoye deposits in the Chernyshevsk district of Chita region with underground, open cut and heap leach to produce 600 tU/yr from 2016.
- However, according to the 2014 'Red Book', both these are on hold.

* 2006 plans were for 2000t/yr at new prospects in Chita Region and Buryatia (Gornoye, Berezovoye, Olovskoye, Talakanskoye properties etc.), plus some 3000t at new deposits.

Buryatia, Vitimsky district

JSC **Khiagda**'s operations are at **Vitimsky** in Buryatia about 570 km northwest of Krasnokamensk, serving Priargunsky's operations in Chita region, and 140 km north of Chita city. They are starting from a low base – in 2010 production from the Khiagdinskoye ore field was 135 tU, rising to 440 tU in 2013 (fully utilising the pilot plant) and targeting 1000 tU/yr from 2018 with a new plant. These are a low-cost (US$ 70/kgU) acid in situ leach (ISL) operations in sandstones, and comprise the only ISL mine in the world in permafrost. Groundwater temperature is 1-4°C, giving viscosity problems, especially when winter air temperature is -40°C. The main uranium mineralisation is a phosphate, requiring oxidant addition to the acid solution. In the Khiagdinskoye field itself there are eight palaeochannel deposits over 15 x 8 km, at depths of 90 to 280 metres (average 170 m). Single orebodies are up to 4 km long and 15 to 400 m wide, 1 to 20 m thick.

JSC Khiagda has resources of 55,000 tU amenable to ISL mining, with resource potential estimated by Rosatom of 350,000 tU, giving a mine life of over 50 years. In 2015 ‘reserves’ were quoted by ARMZ at 39,300 tonnes U. The 2008 ARMZ plan envisaged production from JSC Khiagda's project increasing to 1800 tU/yr by 2019, but in 2013 the higher target was postponed. The 2018 plan is now 1000 tonnes. In 2014 JSC Khiagda continued construction of the main production facility and on the sulfuric acid plant, the first stage of which was commissioned in September 2015. Its final design capacity is 110,000 t/yr.

The company aims to start mining the Istochnoye and Vershinnoye deposits 5-10 km from Khiagdinskoye from 2016 and 2018 respectively, and development of these is proceeding – in fact mining started at Istochnoye in 2015. In 2013 reserves were confirmed for the Dybrynskoye, Koretkondinskoye, Kolichikanskoye and Vershinnoye fields or deposits. The other two fields in the immediate vicinity are Namaru and Tetrakhskoye. All these occur over an area about 50 x 20 km and within 15 km of Khiagdinskoye field. There are also plans to install plant for extracting rare earth oxides (REO) as by-product. The nearest towns are Romanovka, 133 km north of Chita, and Bagdarin.

Sakha / Yakutia, Elkon district

ARMZ’s long-term hope is development of the massive **Elkon** project with several mines in the Sakha Republic (Yakutia) some 1200 km north-northeast of the Chita region. The Elkon project is in a mountainous region with difficult climate conditions and little infrastructure, making it a challenging undertaking. Production from metasomatite deposits is planned to ramp up to 5000 tU/yr over ten years, for RUR 90.5 billion ($3 billion), and 2020 start up was envisaged, but this is now "after 2030". Elkon is set to become Russia's largest uranium mining complex, based on resources of over 270,000 tU (or 357,000 tU quoted by Rosatom in 2015). It will involve underground mining, radiometric sorting, milling, processing and uranium concentrate production of up to 5000 tU/yr.

Elkon Mining and Metallurgical Combine (EMMC) was set up by ARMZ to develop the substantial Elkonsky deposits. The Elkon MMC project involves the JSC Development Corporation of South Yakutia and aims to attract outside funding to develop infrastructure and mining in a public-private partnership, with ARMZ holding 51%. Foreign equity including from Japan, South Korea and India is envisaged, and in March a joint venture arrangement with India was announced. The Elkon MMC developments are to become "the locomotive of the economic development of the entire region", building the infrastructure, electricity transmission lines, roads and railways, as well as industrial facilities, from 2010. Of 15 proposed construction sites, three have been tentatively selected: at the mouth of Anbar River, Diksi Village and Ust-Uga Village. The building of four small floating co-generation plants to supply heat and electricity to northern regions of Yakutia is linked with the Elkon project in southern Yakutia.

There are eight deposits in the Elkon project with resources of 320,000 tU* (RAR + IR) at average 0.146%U, with gold by-product: Elkon, Elkon Plateau, Kurung, Neprokhodimoye, Druzhnoye (southern deposits), as well as Severnoye, Zona Interesnoye and Lunnoye (see above). In mid 2010 ARMZ released JORC-compliant resource figures for the five southern deposits: 71,300 tU as measured and indicated resources, and 158,500 tU as inferred resources, averaging 0.143%U. ARMZ pointed out that the resource assessment against international standards will increase the investment attractiveness of EMMC. However, in September 2011 ARMZ said that production costs would be US$ 120-130 /kgU, which would be insufficient in the current market, and costs would need to be cut by 15-20%.

* 257,800 tU of this was in the five southern deposits. The 2011 Red Book gives 271,000 tU resources for Elkon, or 319,000 tU in situ.

First production from EMMC was expected in 2015 ramping up to 1000 tU/yr in 2018, 2000 tU/yr in 2020 and 5000 tU/yr by 2024 based on the southern deposits as well as Severnoye and Zona Interesnoye. This schedule has slipped by about five years. Also, it is remote, and mining will be underground, incurring significant development costs. ARMZ and EMMC are seeking local government (Sakha) support for construction of main roads and railways to access the Elkon area, and make investment there more attractive.

JSC **Lunnoye** was set up by ARMZ at the same time as EMMC to develop a small deposit jointly by ARMZ (50.1%) and a gold mining company Zoloto Seligdara as a pilot project to gain practical experience in the region in a polymetallic orebody. Lunnoye is expected in full production in 2016, reaching 100 tU/yr. It has reserves of 800 tU and 13 t gold, and is managed by Zoloto Seligdara. ARMZ in mid 2011 expressed impatience with the rate of development.

Further mine prospects

The Federal Subsoil Resources Management Agency (Rosnedra) was transferring about 100,000 tonnes of uranium resources to miners, notably ARMZ, in 2009-10, and 14 projects, mainly small to medium deposits, were prepared for licensing then. They are located mainly in Chita (Streltsovskiy district), Trans-Ural (Zauralskiy district) and Buryatia (Vitimskiy district) uranium regions.

The projects prepared for licensing include:

in Chita Region – Zherlovskoye, Pyatiletnee, Dalnee and Durulguevskoye;
in Republic of Buratiya – Talakanskoye, Vitlausskoye, Imskoye, Tetrakhskoye, and Dzhilindinskoye;
in Kurgan Region – Dobrovolnoye (now licensed);
in Khabarovsk Territory – Lastochka;
in Republic of Tyva – Ust-Uyuk and Onkazhinskoye;
in Republic of Khakassia – Primorskoye.

All together these projects have 76,600 tonnes of reasonably assured and inferred resources, plus 106,000 tonnes of less-certain 'undiscovered' resources.

Rosnedra published a list of deposits in the **Republic of Karelia, Irkutsk Region and the Leningrad Region** to be offered for tender in 2009. In particular, Tyumenskiy in Mamsko-Chuiskiy District of Irkutsk Region was to be offered for development, followed by Shotkusskaya ploshchad in Lodeinopolsky District of Leningrad Region. In Karelia Salminskaya ploshchad in Pitkyaranskiy District and the Karku deposit were offered. None of these 2009

offerings had reasonably assured or inferred resources quoted, only 'undiscovered' resources in Russia's P1 to P3 categories and it appears that none were taken up. In 2016 the Karelia Ministry of Natural Resources and Ecology acknowledged only one uranium deposit “of no commercial interest” at Srednyaya Padma (Medvezhegorsk District) and announced that no mining was planned.

Foreign and private equity in uranium mining

In October 2006 Japan's Mitsui & Co with Tenex agreed to undertake a feasibility study for a uranium mine in eastern Russia to supply Japan. First production from the Yuzhnaya mine in Sakha (Yakutia) Republic is envisaged for 2009. Mitsui has an option to take 25% of the project, and is funding $6 million of the feasibility study. Construction of the Yuzhnaya mine is likely to cost US$ 245 million, with production reaching 1000 tU/yr by 2015. This would represent the first foreign ownership of a Russian uranium mine.

Following from previous deals with Tenex, in November 2007 Cameco signed an agreement with ARMZ. The two companies are to create joint ventures to explore for and mine uranium in both Russia and Canada, starting with identified deposits in northwestern Russia and the Canadian provinces of Saskatchewan and Nunavut.

In addition to ARMZ, private companies may also participate in tenders for mining the smaller and remote uranium deposits being prepared for licensing in Russia. ARMZ is open to relevant investment projects with strategic partners, and Lunnoye deposit is an example where a private company Zoloto Seligdara is partnering with ARMZ.

Mine rehabilitation

Some RUR 340 million (US$10m) is being allocated in the federal budget to rehabilitate the former Almaz mine in Lermontov, Stavropol Territory, in particular Mine 1 on Beshtau Mountain and Mine 2 on Byk Mountain, as well as reclamation of the tailings dump and industrial site of the hydrometallurgical plant. The work will be undertaken by Rosatom organizations under Rostechnadzor. In 2008, rehabilitation of Lermontovsky tailings was included in a federal target program, and over RUR 360 million was allocated for the purpose.

Secondary supplies

Some uranium also comes from reprocessing used fuel from VVER-440, fast neutron and submarine reactors - some 2500 tonnes of uranium has so far been recycled into RBMK reactors.

Also arising from reprocessing used fuels, some 32 tonnes of reactor-grade plutonium has been accumulated for use in MOX. Added to this there is now 34 tonnes of weapons-grade plutonium from military stockpiles to be used in MOX fuel for BN-600 and BN-800 fast neutron reactors at Beloyarsk, supported by a $400 million payment from the USA. Some of this weapons plutonium may also be used in the MHR high-temperature gas-cooled reactor under development at Seversk, if this proceeds.

About 28% of the natural uranium feed sent to USEC in USA for enrichment, and contra to the LEU supplied from blended-down Russian military uranium, is being sent to Russia for domestic use. The value of this to mid 2009 was US$ 2.7 billion, according to Rosatom. See also Military Warheads as Source of Fuel paper.

Russia's uranium supply is expected to suffice for at least 80 years, or more if recycling is increased. However, from 2020 it is intended to make more use of fast neutron reactors.

Fuel Cycle Facilities: conversion & enrichment

Many of Russia's fuel cycle facilities were originally developed for military use and hence are located in former closed cities (names bracketed) in the country. In October 2015 the ministry of economic development moved to open four of these which host facilities managed by Rosatom: Novouralsk, Zelenogorsk, Seversk and Zarechny.

In 2009 the conversion and enrichment plants were taken over by the newly-established JSC Enrichment & Conversion Complex, and in 2010 this became part of TVEL, a subsidiary of Atomenergoprom.